

# विकास VIKAS

A JOURNAL OF DEVELOPMENT

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VOL I • APRIL 2021

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## NEPAL'S POST EARTHQUAKE RECOVERY & RECONSTRUCTION SPECIAL ISSUE



GOVERNMENT OF NEPAL

National Planning Commission  
Singha Durbar, Kathmandu



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National Reconstruction Authority  
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VIKAS

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NEPAL'S POST EARTHQUAKE RECOVERY & RECONSTRUCTION

SPECIAL ISSUE

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Published by:



National Reconstruction Authority  
Singha Durbar, Kathmandu



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Singha Durbar, Kathmandu

Websites:

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National Reconstruction Authority  
National Planning Commission

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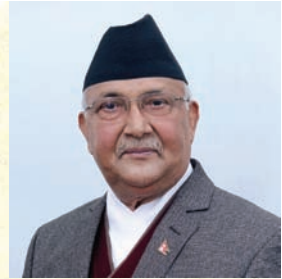
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*The Prime Minister*

## Message



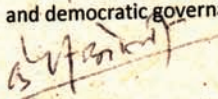
I am pleased to learn that the National Reconstruction Authority and National Planning Commission have come up with the journal *Vikas* for publication, with a focus on the considerable progress achieved, as well as the challenges faced, in reconstruction in the years following the 2015 Gorkha, Nepal earthquake. The publication is both appropriate and timely. The earthquake killed over 8,000 people and damaged close to a million homes, as well as many public offices, classrooms, health facilities and cultural heritage sites. The massive reconstruction effort was a challenge unlike any other faced in Nepal's recent history. It covered a vast area of rugged terrain. While Nepal may not be a wealthy country in financial terms, the recovery process has proven, once again, our richness measured in the resourcefulness of our people and their determination to restore the country's economy, social fabric and unmatched cultural heritage.

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 sincerely thank the Nepal Reconstruction Authority for providing the leadership of this massive reconstruction effort and the many development partners who assisted in this huge national undertaking.

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. The current issue of *Vikas* – and, I hope, other similar publications that will follow – assists us in this purpose by providing evidence-based knowledge, on the basis of which we can take pride in our achievements and also draw lessons from shortcomings identified.

I look forward to seeing other issues of *Vikas* debating these interrelated themes of sustainable development, disaster risk management and post-disaster reconstruction. Together, such multi-faceted analyses can provide valuable insights and feedback into 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, and provide a strong foundation for making our nation resilient towards any potential future disasters and thereby assist us in attaining our vision of a 'Prosperous Nepal, Happy Nepali'.

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.

  
K P Sharma Oli  
10th April 2021





## National Reconstruction Authority



### Foreword

I am delighted to share with you the first of a series of National Reconstruction Authority (NRA) and National Planning Commission publications that recount our experience in reconstruction and rehabilitation after the 2015 Gorkha, Nepal earthquake. The publication series will provide lessons for future generations in our own country and will also inform people all over the world, who face natural disasters with increasing frequency.

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 completed the reconstruction of over 800,000 houses, about 50,000 classrooms at 10,000 schools, 1200 health institutions and about 1800 cultural and historical monuments, including monasteries. In addition, NRA-led efforts have also rebuilt 750 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 preoccupations. We have likewise supported the restoration of livelihoods, new roles and working opportunities for women and have sought to develop special provisions for 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 supporting the enormous task of reconstruction.

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

Sushil Gyewali  
Chief Executive Officer  
National Reconstruction Authority





## National Planning Commission



### Preface

The National Planning Commission (NPC) is glad to publish this issue of *Vikas* as a collaborative effort, together with the National Reconstruction Authority (NRA). In the immediate aftermath of the Gorkha earthquake, the NPC played a catalytic role in the preparation of 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 and execution in Nepal and beyond.

The NPC is committed to working towards policy reforms based on the NRA lessons. NRA's work included five different but related thematic areas: private housing, heritage, public building and infrastructure, livelihood and governance. At each step, the needs of particular population groups and regions of the country had to be taken into account. The core of NRA's learnings is related to promoting resilient housing and infrastructure, to withstand the impacts of future earthquakes and other natural disaster events. We have to reassess our land use systems, the availability of technology at the end user level, access to finance, and the Government's delivery mechanisms at all levels in our federal system and to all sectors of society. 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 and especially with the most vulnerable beneficiaries of reconstruction programmes.

I wish to highlight in particular two issues addressed in the papers in this volume: strengthening national capacity in the heritage sector and promoting resilient private housing through retrofitting and reconstruction. The NPC will promote discourse on capacitating national institutions for the conservation of our heritage monuments and sites. For this to succeed, some institutional realignment and support of both federal and local governments, as well as of civil society, may be required. The country has already begun work on reinvigorating the disaster management agenda, with the mandatory implementation of the existing Building Standards. We will also initiate a national debate on reinforcement of existing housing stock through retrofitting, to facilitate increased resilience to future disaster shocks. With the benefit of the NRA's experience and technological innovations, it will definitely be easier to extend such retrofitting to municipalities beyond those covered by post-Gorkha earthquake reconstruction.

This joint publication is 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 to our development and disaster management processes nationwide.

Purna Raj Kandel

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 a range of lessons learned activities, which will culminate in the International Conference on Nepal's Reconstruction (ICNR-2021), to be held later this year. The Rt. Hon. Prime Minister K.P. Sharma Oli, who chairs both NRA and the NPC, deserves our heartfelt appreciation for the leadership provided to the reconstruction and recovery activities, including preparatory work on the ICNR. Mr. Sushil Gyawali, the NRA Chief Executive Officer, has led and guided the ICNR preparatory activities. The understanding of Dr. Puspa Raj Kadel, Vice Chairman, NPC on the need to document learnings was instrumental in planning this publication. We also extend our gratitude to all members of the ICNR Organizing Committee for their constructive contributions during the process.

The Editorial Board Members, Prof. Dr. Tara Nidhi Bhattarai (Editor in Chief), Mr. Basu Dev Sharma, Dr. Nigel Fisher, Prof. Dr. Ram Manohar Shrestha and Mr. Jitendra Bothara assisted us in reviewing the substance and structure of the many learned papers prepared. Similarly, all peer reviewers worked to the highest academic and professional standards to assist the authors in completing their contributions. Mr. Binod Bhattarai, Ms. Pratibha Tuladhar 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. Dr. Adi Walker, Director of the European Union (EU)-funded NEARR Facility, represented the Development Partners at the Secretariat, with the support of Mr. Shyam Sundar Sharma and Mr. Sandeep Gurung. The facility has provided financial, technical and logistical assistance for the preparatory activities. We are thankful to both the EU and the NEARR Facility for their support.

The NRA and NPC task team bridged two different organizations, producing an output agreeable to both agencies, while meeting acceptable publication standards. This team was 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). Last but not the least, we would also like to acknowledge Mr. Pradip Acharya and Mr. Janardan Nepal for their contribution to facilitating ICNR related activities.

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

Mani Ram Gelal  
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 (known as the Compendium), institutional and open routes. This publication of the special issue of *Vikas* emanates from the scientific route. Articles of international interest have been planned for publication 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, 10 of which are included in this volume. All the articles have policy and implementation-level implications.

The article on heritage conservation argues for the need to bolster national capacity across the heritage sector, which has remained sidelined in terms of institutional architecture, resource allocation and human resource development. Enhancement of the heritage sector requires rethinking, both for conserving our national identity and to increase tourism income.

The NRA tried out a number of housing retrofitting technologies that were robust, cost-effective and replicable. This volume contains several articles on reconstruction, retrofitting and the use of various construction technologies and methods.

One article has reviewed the housing sector from the social perspective. The size and cost of houses, housing needs and availability of resources have also been analyzed. The learning and recommendations derived from these articles can support future policy formulation. Another article deals with NRA's experience in the resettlement of displaced people. NRA's strategies to grapple with the problems faced by landless households have also been discussed. Housing is not only a technical and economic product, but also a social creation, which is often overlooked. This aspect has been discussed in this volume, as a comprehensive outlook is required for developing sound policy formulation and implementation strategies.

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

Chandra Bahadur Shrestha  
Executive Committee Member, NRA  
Convener, ICNR



## Editorial

This 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 to lead and coordinate the post-earthquake reconstruction.

The NRA was instituted nine months after the main shock of April 25, 2015. Five years after the establishment of the Authority, a significant number of achievements in reconstruction and recovery had already been recorded. It was evident that it would be extremely useful to share these achievements at local, regional and international levels, as a means of helping others to prepare for earthquakes and other disaster events in the future and to mitigate the resultant impacts likely to be encountered.

As a first step in the information-sharing process 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. The webinar is the precursor to an International Conference on Nepal's Reconstruction, which is planned to be held later in 2021 (ICNR -2021). The NRA's ICNR Conference Organizing Committee is responsible for oversight of all preparatory activities leading up to the ICNR, including the preparation of this special issue of *Vikas*.

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 situation, 62 completed papers were submitted. These were assigned for a double-blind peer-review process. The papers were presented thematically at the NSNR – 2020, during which authors received suggestions and feedback from audience

members, panelists and facilitators. The papers of those authors who addressed reviewers' comments and seminar feedback satisfactorily, were accepted for the publication in the proceedings of the webinar.

The NRA made two provisions for the publication of manuscripts: in *Vikas*, the journal of the National Planning Commission (NPC), Government of Nepal, and in *Progress in Disaster Science (PDS)*, an international journal published by Elsevier. Based on the suggestions of the peer reviewers and of the editors, authors of accepted papers were requested to indicate their preference for publication of their manuscripts in either journal. This volume consists of the papers submitted to *Vikas*.

The papers included in *Vikas* cover a number of important areas of reconstruction, including private housing, cultural heritage, governance and other cross-cutting issues. We believe that these papers will be useful to researchers, policy makers, students and general 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. Most importantly, the papers will serve as a mirror reflecting how Nepal completed its reconstruction after the 2015 Mw 7.8 Gorkha, Nepal earthquake.

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

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### Editorial Board

**Tara Nidhi Bhattarai** (Editor-in-Chief)

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## Strengthening the National Capacity for Conservation of National Heritage Monuments and Sites

Chandra Bahadur Shrestha<sup>a</sup>, Bishma Banskota<sup>b</sup>

*Key words: heritage monument, archeology, constraints, conservation capacity.*

### Abstract

Nepal's national capacity in the heritage sector is not adequate for addressing the reconstruction challenges. Owing to weak implementation capacity, only 42 percent of monuments that were damaged by the 2015 Gorkha Earthquake had been renovated in the second trimester of FY 2019/2020 when it should have been completed. This has put Nepal's cultural identity at risk, which could adversely affect tourism income. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has been considering the inclusion of Nepal's World Heritage Sites (WHS) in its endangered list that underscores the urgency for their upkeep. This study aims to identify constraints and weaknesses in the heritage sector reconstruction and recommend ways for effective conservation of Nepal's cultural monuments and sites. This study used secondary data to obtain information on the status of Nepal's heritage sites, mainly from the Department of Archeology's (DoA), freelance archeologists, former government officials, renowned conservationists and historians. It also includes observation findings of key heritage reconstruction sites and information from key informants. It concludes that the Government of Nepal (GoN) will need either to have a Ministry of Culture and Archeology or institute a dedicated authority under the Prime Minister's Office for effective restoration and conservation. Similarly, the Ancient Monuments Preservation Act and Rules need to be amended in accordance with the spirit of the Constitution and also to include changes in legal instruments to facilitate research, account for historical trails and to ensure effective maintenance. The organizational structure of the DoA also requires changes to include sections to undertake analysis of structure, material and technology of heritage monuments alongside planning of heritage sites. There is also need to consider engaging and supporting the private sector through capacity building provisions, promoting industrial districts for the heritage – related enterprises, and propagating traditional architecture and construction materials for conserving traditional architecture. These interventions are expected to ensure sustainable conservation of heritage monuments and sites, strengthen national identity and foster economic development.

### 1. Introduction

The United Nations Educational, Scientific and Cultural Organization (UNESCO, 2020) states that heritage

sites are symbols of history that serve as laboratories for demarcating and understanding regional laws and social structures. This understanding can assist the progress towards an ideal society as it enhances

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our proximity to distant societies and communities, exposes us to social instincts for perfection and struggle for survival that are largely similar. Heritage sites are our connections to ancestors and provide insights into our existence and evolutionary processes. Further, the contribution of heritage sites economically both at the national and global levels are seldom left unassessed. In Nepal, the tourism sector contributes around five percent of Nepal's Gross Domestic Product (GDP) of over US\$ 28,539 million in FY 2017/18 (Mahatara, 2019) of which the heritage sub-sector in tourism may have contributed around two percent or about US\$ 570.78 million.

The overall progress in heritage sector reconstruction was only 49 percent in end FY 2019/20. About 40 percent monuments were under construction in 2019/20 (THT, 2020) while the reconstruction of 42 percent monuments had yet to begin. The progress on the rebuilding of WHS sites in Kathmandu Valley was slightly higher and around 62 percent monuments had been completed. The progress of non-WHS monuments progress only 48 percent and the overall progress of heritage reconstruction outside Kathmandu Valley was 45 percent. In end 2020 there were 389 candidate monuments for reconstruction where work had yet to begin.

If the contribution of Non-Governmental Organizations (NGOs) and local governments is discounted, the real contribution of the Department of Archeology (DoA) decreases substantially. Fifteen monuments were restored by the Kathmandu Valley Preservation Trust (KVPT) in Patan Durbar Square (Poudel, 2020). KVPT also rebuilt four temples in the Hanumandhoka Durbar Square. Of 21 earthquake damaged heritage monuments, nine were restored by user committees under the auspices of the Bhaktapur Municipality (Aryal, 2019). Similarly, the Kathmandu Metropolitan City has been reconstructing the Kastamandap and Maju Dega (Ojha, 2020). Further, a number of heritage monuments in the Kathmandu Durbar Square were reconstructed with foreign assistance. For example, the reconstruction of the Nine Story Basantapur Tower has been underway with

assistance of the People Republic of China and the Gaddi Baithak was renovated with assistance from the United States of America.

The DoA initiated the rebuilding of some monuments but was unable to complete construction, one example of which was the Ranipokhari, located in the heart of Kathmandu (Chaudhari, 2018; TMC, 2018). The Department also initiated reconstruction of the Balgopaleswor Temple but had to back down later, essentially because of the debate over the use of reinforced cement concrete by Kathmandu Metropolitan City after securing DoA's approval, which the DoA denied. The reconstruction of Rato Machhindranath also took a long owing to the DoA's inefficiency (Brush, 2019).

UNESCO has listed Nepal's Hanumandhoka Durbar Square, Patan Durbar Square, Bhaktapur Durbar Square, Pashupati Temple, Changunarayan Temple, Boudha Stupa and Syambhu Stupa as World Heritage Sites (UNESCO, 1979). These historical monuments were damaged by the 2015 Gorkha Earthquake, causing UNESCO to propose the including Kathmandu Valley World Heritage Properties in its endangered list, mainly owing to slow progress in restoring the heritages. A joint reactive monitoring mission of UNESCO's World Heritage Center, International Council on Monuments and Sites (ICOMOS) and International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) (Jing et al., 2017) had concluded that the monuments had further deteriorated in 2017. The mission had emphasized the need for developing a coherent and coordinated recovery plan. Four years after the earthquake the progress in reconstruction stood at only 42 percent and some major restoration tasks had been handed over to the Central Level Project Implementation Unit (CLPIU- Building) while others were taken up by the National Reconstruction Authority (NRA). Further, Nepal has a shortage of human resources with the necessary skills and interest to work in the production of heritage products, while there are only a limited number of producers producing traditional bricks and wooden carvings.

The objective of this study is to propose measures for developing national capacity based on the identified constraints in the heritage sector in Nepal. The study is expected to generate a debate on challenges facing the heritage sector that could lead to mechanisms for sustainable conservation of heritage monuments and sites that can make contributions towards enhancing Nepal's national identity, create jobs and also provide opportunities for the global community to learn about Nepal's arts, cultures and history. The article does not discuss intangible cultural heritage, an equally important focus of conservation, which is a limitation of this study.

## 2. Research design

The following sections discuss the scope and analytical framework of the study.

### 2.1. Scope of the research

The study has included only the historical monuments and sites, under the jurisdiction of the DoA. This includes Patan, Bhaktapur, Hanumandhoka Durbar Squares, Pashupati Area, Changuarayan Area, Boudha Area and Swayambhu Area. All these seven are Kathmandu Valley World Heritage Zones. Table 1 shows the status of reconstruction of 920 damaged monuments under the DoA. The total number of damaged heritage monuments was 2828.

### 2.2. Analytical framework

As shown in the analytical framework (Figure 1), the study reviewed documents on the damage to Nepal's monuments available at supranational agencies such as UNESCO and ICOMOS. The review included the ICOMOS Charters for conservation and restoration that are fundamental guidelines for reconstruction, repair and maintenance. Among them the Venice Charter 1964 defines conservation, restoration, historic sites, excavation and publication (ICOMOS, 1964). UNESCO's Budapest convention in 1972 elaborated the international mechanism of heritage conservation and has not only defined cultural and natural heritage but also elaborated on the responsibilities of national and international agencies. For example, national governments are expected to develop policies and define territory of heritage sites. Thereafter the international community agreed to establish the "World Heritage Fund" and set conditions for international assistance.

The Constitution of Nepal (Parliament of Nepal, 2015) has divided responsibility for restoring heritage monuments and sites to the federal, provincial and local governments. However, the law required to operationalize this remained to be enacted in 2020. The Ancient Monuments Preservation Act (AMPA) 2013 (GoN, 2017a) and Ancient Monuments Preservation Rules 2046 (GoN, 1989) are two legal instruments that relate to the conservation and restoration of historical monuments and heritage sites. The study team

Table 1: Status of Reconstruction of Monuments damaged by 2015 earthquake

Description	Total Damaged Nos.	Completed	%	Ongoing in FY 2019/20	%	Remaining	%
World Heritage Site	170	101	59	52	31	17	10
Kathmandu Valley Districts	404	159	39	165	41	79	20
Outside Kathmandu Valley	346	129	37	148	43	70	20
<b>Total</b>	<b>920</b>	<b>389</b>	<b>42</b>	<b>365</b>	<b>40</b>	<b>166</b>	<b>18</b>

Source: (NRA, 2020b)



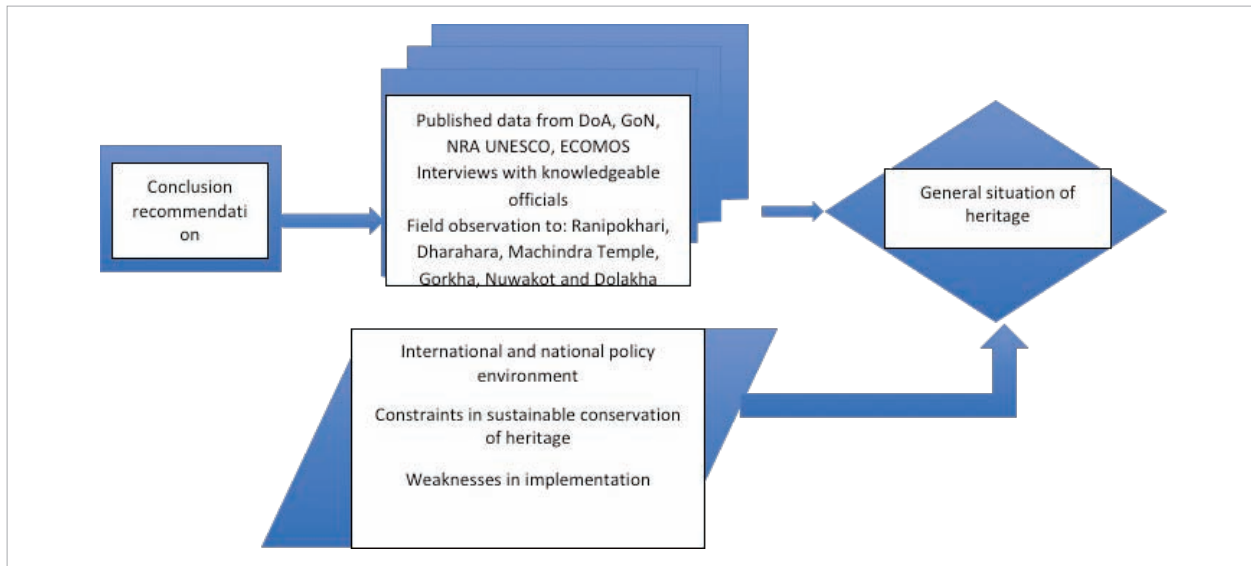


Figure 1. Analytical framework

carried out additional reviews of literature related to developing national capacity for the conservation and restoration of heritage monuments to respond to the objective of undertaking a systematic analysis of capacity development based on real requirements.

Information collected from secondary sources were validated with that obtained from DoA officials. A number of comprehensive open-ended interviews were done with the DoA officials on institutional constraints, contractual issues, monitoring of construction and some of the conceptual issues. One focus group discussion including responsible DoA officials, NRA officials, and mayors of Tokha and Gorkha municipalities was also organized. The study team also collected information from six heritage locations: Ranipokhari, Dharahara, Machhindranath Temple, Bungmati, Gorkha Durbar and Dolakha heritage sites. The study team observed the reconstruction work and approaches, construction materials and architecture, and did a number of interviews with engineers, masons, carpenters and user committee members and contractors at these sites.

All information collected from primary and secondary sources was compared, collated and synthesized

and some secondary information was also used to illustrate or justify some phenomena. Each finding was rigorously discussed to arrive at the conclusions.

### 3. Research findings

The study has identified both constraints and weaknesses in Nepal's heritage sector. The constraints were largely beyond sectoral control under existing policies and laws, whereas there was room for sectoral efforts to exert some degree of control over the weaknesses.

#### 3.1. Constraints in the heritage sector

The DoA is mandated to undertake research on the historical, cultural, religious and archaeological heritage of the country. Protection and maintenance of archaeological sites, ancient monuments, museums and archive management are among the DoA's responsibilities. The Department is also accountable for the conservation of monuments, sites, and even vernacular edifices across Nepal – private or public – provided they have archaeological, historical, artistic and aesthetic value (DoA, 2020). Taking into account this mandate, the

NRA had entrusted the DoA the task of restoration of all earthquake-damaged monuments. However, the Department had completed only 42 percent of the task in March 2020, while the NRA term was to have ended in December 2020. There were controversies at some of the sites of restoration, which the NRA later had to take over to ensure timely completion.

The DoA's decision-making capacity was weak as demonstrated in the restoration of Ranipokhari, a historical pond in the center of Kathmandu, which became controversial after the Department began the restoration work in January 2016, particularly over its plan to use reinforced cement concrete for restoration, instead of the traditional stone boulder, brick and clay (The Kathmandu Post, 2018). The second controversy was on the proposed architecture of the monument at the center of the pond. It is said that the monument originally had the Granthakuta (Sikhara) style and had been modified to Gumbaj (dome) architecture by Jung Bahadur Rana, the first Rana prime minister of Nepal (Tuladhar, 2020). The question was whether the reconstruction plan should build in the original Granthakuta Style or adopt the Gumbaj style. The DoA's official position to rebuild the monument to match the structure damaged by the 2015 earthquake (i.e., Gumbaj style) but had to yield to both social and political pressure demanding that the monument be rebuilt in the original Granthakuta style (NS, 2019). On this issue DoA had to take the final decision. However, the Council of Ministers decided to have the monument reconstructed by NRA, which began work by demolishing the DoA-erected concrete structure. The NRA used traditional construction materials and adopted Granthakuta Style (NRA, 2019) for the reconstruction that was completed in 2020.

The reconstruction of the Ranipokhari pond had controversial. The Kathmandu Metropolitan City (KMC) had initiated the reconstruction after securing DoA's approval on the design of the pond that included fountains and a new lakeside café. For this, KMC had demolished traditional walls and replaced them with reinforced cement concrete structures. After a series of local protests, NRA decided to restore the pond

to the way it was when first built in BS 1614 (Aryal, 2019). As result the concrete walls had to be pulled down and replaced with the original structure using traditional materials.

Similarly, the DoA was unable to implement the conservation plan of Bagdurbar, another neoclassical building, which was enmeshed in a debate on whether the choice should be reconstruction or retrofitting. The issue eventually reached the Supreme Court and a decision had not been taken in end 2020. Further, the restoration of the Lal Vaithak at Bhaktapur Durbar Square had not started in April 2020 owing to debate on the architectural approach (Dawadi, 2018).

The DoA failed in taking well-considered decisions on the issues above and the changing decisions resulted in wastage of both time and resources. More importantly, the situation raised questions on the DoA's capacity and credibility. The experiences discussed above suggested the need to enhance DoA's capacity to take decisions based on proper geological, architectural assessments, and historical logic.

Further, as discussed in the background section, the experience suggested that national policy makers have not accorded appropriate importance to an institution as important as the DoA. Since its establishment in 1952, the Department's stewardship has been shifted eight times, under different ministries (DoA, 2020), which had their own primary mandates and the archeological responsibility remained subordinate to other functions. It is therefore quite natural for the minister in charge to represent mainly the mainstream activities of the ministry in the Council of Ministers trivializing archeological issues compared to the main ministerial mandate (for example, tourism and civil aviation). Therefore, in the absence of adequate attention, the DoA has been largely unable to secure the required strength and capacities in its area of responsibility. For example, the Department did not have accurate records of all tangible historical monuments in the country, suggesting the need for having detailed records based on scientific study of each historical, cultural, religious and archaeological monument and sites. Further, the DoA did not have a functional research wing to keep



track of the state of different monuments that have not been maintained properly. Almost all heritage monuments had leaking roofs with weed growth on the roof, which had happened because there was no authoritative instruction supported by human and financial resources for regular upkeep. All of these reasons have prevented the establishment of the DoA an institution capable and credible for stewardship of Nepal's heritage.

### 3.2. Weaknesses in the heritage sector

The study has identified three weaknesses in the heritage sector: an outdated law (AMPA), UNESCO's unaddressed concerns about Nepal's conservation efforts, and insufficient involvement of the private sector in heritage conservation.

#### 3.2.1. Ancient Monuments Preservation Act 1956

The Nepal's Constitution – 2015 mandates shared responsibility for conservation, renovation and management of cultural heritage and monument sites among the federal, provincial and local governments (GoN, 2017b). The AMPA was prepared before the promulgation of the 2015 Constitution and therefore did not incorporate the sharing of responsibility. The AMPA has classified monuments as international, national and local and requires DoA to conserve and maintain all public monuments. This classification requires a review in the light of the provisions of the 2015 constitution. The responsibility of conservation, maintenance and renovation for international and national heritage monuments lies with DoA directly. The responsibility of provincial level monuments can be handed over to provincial governments and local level monuments and sites to the local governments. However, DoA would need to engage with the provincial and local governments on research and techniques of conservation, maintenance and restoration. The AMPA therefore needs to be amended to spell out these issues.

The AMPA rules have a provision for an Ancient

Monuments Conservation Cooperation Committee with representation from all formal institutions. However, almost all heritage monuments have some association with local social groups who take care of them. Such groups, however, have no representation in the committee. These groups need to be included as it will be extremely difficult to implement any restoration plan without local involvement.

Nepal has thousands of Gumbas (monasteries), Stupas (a mound-like or hemispherical structure containing relics that is used as a place of meditation), Chaitya (a prayer hall or temple containing a Stupa) and heritage sites dedicated to Lord Buddha (Sharma, 2017). However, most of them are not properly documented. NRA conducted surveys in all the 32 districts affected by the 2015 Earthquake for identifying damaged monasteries and found that there were 1320 that required maintenance (Dangal, 2019). At present, only Lumbini, Soyambhu, Boudha and Namura (Namo-Buddha) are under the DoA's oversight. For this, AMPA needs to also spell out conservation procedures of such Buddhist holy shrines.

The Chief District Officer (CDO) – a federal government employee – is tasked with information collection on new archeological objects. However, in the changed context, authority of conservation of heritage monuments and sites lies with local governments. Under this arrangement it would be logical to have the Executive Officer of the Municipality responsible for the task undertaken by the CDO. Alternatively, it can be the responsibility the executive heads of local governments. Municipalities that have traditional heritage settlements or heritage sites and monuments need to have institutional structures with sufficient human and financial resources for the conservation-related works.

AMPA has provision for heritage settlements, which are required to comply with some probationary provisions. For example, rules an individual household should follow while laying water or sewerage pipes or other facilities in heritage settlements. However, this clause does not relate with reality, where an individual does not have much influence on these utility systems. The DoA is required to prepare a plan for such heritage

areas to make available to the utilities in collaboration with utility service providers. Thus, the DoA's role should be that of an enabler rather than an imposing authority. The Act, when amended, also needs to have provisions clarifying how the DoA should collaborate with the local governments, particularly the roles and responsibilities of local government as well as the local communities.

The DoA's Mission spells out a number of activities it has to execute. However, conducting heritage research is only implicit in both the Act and Rules. Having extremely low-profile research at the Department could have been reason of its exclusion from the Act and Rules. Similarly, the Act intends to allow external parties to explore and excavate heritage sites rather than making this an undertaking of the DoA.

Therefore, in general it is apparent that there are no direct links between the law and the roles and responsibilities of the Department. There are a number of areas where the provisions of the Act have not been reflected in the rules. For example, the rule should have specified an elaborate process for declaring heritage sites, including required forms and formats, which should have been ideally guided by the law. More importantly, there was little coherence between the Act, rules and actual practice. For effective conservation organizations, it is imperative that the law has direct linkages with the rules.

### 3.2.2. UNESCO's inclusion of Nepal's World Heritage Sites in the Endangered list

UNESCO had been raising concerns with regards to the upkeep of Nepal's World Heritage Sites for a long time. The housing construction architecture and methods used around Boudhanath and the proposed road that would bisect the Pashupatinath Zone were some major concerns (Xinhua News Agency, 2013). However, the destruction of heritage sites inflicted by 2015 Gorkha Earthquake led to other serious concerns (Jing et. al., 2017). While acknowledging considerable progress in heritage conservation, Jing et. al. indicated major threats as being: poor coordination between major

stakeholders, lack of capacity (architectural expertise and experience in heritage conservation) and resources (human, technological and financial) within the DoA; lack of a recovery master plan for each of the monument zones; lack of protection for severely damaged monuments to ensure that they suffer no further deterioration; lack of adequate documentation of damage caused to the monuments by the earthquake; lack of adequate record keeping, including centralized collection and storage of all relevant documents; and lack of evidence and values-based decision making for the recovery of monuments. Additionally, the UNESCO report also pointed out other issues: use of inappropriate construction methods and materials, as a result of the open tender system used for recruiting contractors to undertake repair and reconstruction of monuments; lack of adequate monitoring; and inadequate planning with local communities. The loss of traditional housing in all urban monument zones and ancient settlements, and new and uncontrolled urban development within the monument and buffer zones, were the other major concerns. Although, the DoA has been working address UNESCO's concerns and has made some reasonable progress, its efforts so far have been largely inadequate to satisfy UNESCO's concerns.

## 4. Discussion

Removing the constraints and strengthening areas of weakness would require actions in three three major areas: policies to address the constraints, measures for strengthening the DoA, and strategies for attracting private sector to engage in heritage conservation.

### 4.1. Policy options for resolving the constraints

The findings and analysis in the previous section has revealed the need to strengthen national capacity for conservation of heritage monuments and historical sites and it is likely that there would be further deterioration if the existing situation remains unchanged. UNESCO's call for declaring Nepal's World Heritage Sites as "endangered" internationally has yet to be

taken seriously within Nepal. Similarly, enhancing the capacity of the DoA would require institutional restructuring, amending relevant laws and rules, and also revising the DoA's organizational structure.

#### 4.1.1. *Establishing a powerful heritage entity*

The efforts of put in place a capable heritage sector needs to start at the strategic level. There are two options: a) establish a new Ministry of Culture; b) establish a National Archeological Authority under the Office of the Prime Minister. Different countries have various arrangements for heritage conservation.

In China, the Ministry of Culture and Tourism (MoC&T) is responsible for cultural policy and activities, including managing national museums and monuments; promoting and protecting the arts; and managing the national archives and regional culture centers (MoC&T, 2020).

Similarly, in 1997, the United Kingdom government established the Department of Digital, Culture, Media and Sport (DDCMS, 2020) with policy responsibility for museums, galleries and libraries; built heritage; the arts, sport, education; broadcasting and media and tourism; and the Millennium and National Lottery. DDCMS formulates policies for the protection and promotion of heritage, and most importantly, it also bids for funding from the treasury for its areas under its mandate and allocates a budget to bodies such as English Heritage to implement its policy. The Office of the Deputy Prime-Minister (OPDM) is mandated to prepare the planning policy and for providing legal protection through the process of scheduling ancient monuments (including archaeological sites) and listing historic buildings.

In Thailand, the Ministry of Culture (MOC), is responsible for the oversight of culture, religion, and arts. In addition to the Minister and Secretary of the Ministry, there are other departments such as: Provincial Cultural Office; Religion Affairs Department; Fine Arts Department; Department of Cultural Promotion; Film Censorship Board (FCB); Office of Contemporary Art and Culture and the Buditpatanasilpa Institute (MoC-Thailand, 2020).

In Italy, the Ministry of Cultural Heritage and Activities (MoCHA, 2020) is responsible for conserving heritage sites. It is principally concerned with culture, the protection and preservation of artistic sites and property, landscape, and tourism. In 2009, the Ministry's organizational structure underwent significant changes (Decree 91/2009): the coordination of ministerial functions still remains entrusted to a Secretary General, the General Directorates have been reduced from nine to eight, with new denominations and reshaping of their responsibilities. The eight General Directorates continue to be technically supported by high level scientific bodies.

In India, the Archeological Survey of India is a unit under the Ministry of Culture. The major responsibilities of the ministry are maintenance and conservation of heritage, historic sites and ancient monuments, administration of libraries; promotion of literary, visual and performing arts, observation of centenaries and anniversaries of important national personalities and events, promotion of institutions and organizations of Buddhist and Tibetan studies, promotion of institutional and individual non-official initiatives in the fields of art and culture, and entering into cultural agreements with foreign countries (MoC, 2020).

As stated above in all the five countries, heritage conservation is a function under the Ministry of Culture with some country-specific variations. This international practice shows that Nepal also should have one Ministry of Culture to oversee heritage monuments and sites. The advantage of this arrangement is that the vitally important sector would receive proper attention. The ministry will have access to the Council of Ministers, the body for making policy decisions and would also be able to access financial resources. There is, however, a major obstacle to having this arrangement, particularly the general perception that the size of the Federal Government should be small, with less than 25 ministries. At present, there are 22 ministries. Another option is to form a dedicated authority under the Office of Prime Minister with a Special Charter Act. The authority could be focused on heritage only – culture can continue to be associated with tourism.



There are a number of benefits with this arrangement, including having an area of focus and it would report directly to the Prime Minister, giving it strong leverage. However, the downside of this would be the other preoccupations of the Prime Minister that could mean inadequate time for looking into matters relating to the heritage authority.

#### 4.1.2. Amendment of Heritage Act and Rules

The law and rules to guide heritage conservation in Nepal are outdated and need to be amended taking into account the macro-level institutional landscape. If the government decides to form a Ministry of Culture to oversee heritage conservation then the law has to be amended accordingly. If the government decides to have an authority instead it would also need to enact a new law. There is also a third possibility under which the government could wish to maintain the status quo. However, the law and rules would need to be amended even under the status quo scenario to ensure effectiveness of the DoA in the management of heritage sites. When amended, the AMPA would need to create a basis for classifying heritage monuments and sites to match the functions of the federal, provincial and local jurisdictions. When this becomes effective, the respective jurisdiction has to assume accountability for maintenance while ensuring that the maintenance procedure is authenticated and approved by the Federal entity, the DoA.

In case of the discovery of a new archeological object, it is the responsibility of the Chief District Officer to report to the DoA. This responsibility needs to be transferred to local jurisdictions under the federal governance arrangement.

The existing law has adopted a top-down approach for providing infrastructure facilities in heritage settlements. The provision requires the inhabitant to apply for permission to construct a house and for receiving public services. However, this approach does not consider supply side interventions. Heritage areas need plans for providing public facilities such as water supply, electricity and telephone. For this, each

heritage site would require a Master Plan to ensure historical monuments are portrayed attractively and maintained properly, while also taking measures to ensure livelihood opportunities for local populations.

There are a number of areas which require further research. Firstly, detailed record-keeping with photographic evidence, sketches, drawings and measurements are required. This is because monuments could collapse during disasters and such records can assist restoration. Secondly, there is an immediate need for carrying out in-depth structural analyses of historical buildings. Experts believe that the Lichhivi, Malla and Shah era technicians might have some form of understanding of earthquakes and geology and they may have designed heritage structures to counteract such disasters. However, in the absence of proper records and inter-generational transfer of know-how, the knowledge of our ancestors might have already been lost and therefore the need to research. The third area of research is on traditional construction materials and how they interact with various types of natural forces? Other question to which answers need to be sought are: Are we able to produce similar quality of construction materials as in Lichhivi, Malla or Shah era? What are the traditional methods used for strengthening structures? Can we recycle the original construction materials? What will be the impact on structural strength in the use of recycled materials? Finally, there is need for detailed studies on the architecture and structures of historical monuments and sites. Other research areas could be on chemistry and reactions of chemicals on traditional building materials, diagrams and coins, post-disaster archaeological study of foundations, geological investigations, and studies on effective conservation of artefacts, architectural elements, and murals.

#### 4.2. Measures for strengthening the DoA

The major problems faced by the DoA are the mismatch between the skill sets required and the provision of human resources, and the inadequacy of financial resources. First of all, the DoA needs to be made

compatible in terms of its functions in the federal administrative set up, with representation in each province. Based on this line of thinking, what it essentially needs is representation in six provinces with the Head Office also being made responsible for Bagmati Province. Each provincial office should have at least one archeological officer, civil engineer, architect and some draftspersons, with responsibilities including conservation and renovation of all historical, cultural and religious monuments under the DoA's purview. Such a unit also needs to be required to support the DoA provincial office as well as local governments to conduct heritage research, conservation and renovation of heritage monuments.

The DoA has been essentially functioning as an organization for regulating the exploration and excavation of archaeological sites. However, it should have a designated excavation team in-house or have a contractual agreement with capable institutions and universities. At the central level, there is also need for enhancing DoA's capacity, and one area for that is research. The National Research Institute for Cultural Properties, Tokyo (NRICP, 2016) has indicated that historical buildings in Nepal might have some mechanisms for earthquake resistance, which is largely unknown and needs to be researched. Also unresolved is the issue of whether or not to build earthquake non-resilient structures because it was the way they were before. ICOMOS states that in situations where traditional techniques prove inadequate, the consolidation of a monument can be achieved by the use of any modern technique for conservation, the efficacy of which has been shown by scientific data and proved by experience (ICOMOS, 1964). Based on this provision, the DoA needs to develop norms and specifications for restoration or repair and maintenance and discuss it nationally and internationally to arrive at a decision. Thereafter, all heritage restoration could be guided by the document. However, before that can happen the DoA would need to be made capable of undertaking the historical responsibility.

The DoA would need an appropriate organizational structure to address the issues mentioned above. It could

do this by ensuring that the required human resources are available in-house or by having an arrangement that would allow it to be a lean organization and procure the required expert and institution services on need basis. A combination of the approaches above could be the third strategy. Based on characteristics of Nepal's administrative system, it may be sensible to have minimum human resources within the organization and hire services on a need basis.

In addition to heritages discussed above, Nepal has an extensive network of heritage trails, which could have valuable archeological treasures. However, most of the trails are being replaced by motorable roads. Realizing the importance of trails, the International Center for Integrated Mountain Development (ICIMOD) conducted a study in the Kailash Sacred Area Region in Humla district (Shrestha, C.B., Lama, Tshewang, Meyer, W.P., Schneider, G., 2010). The Nepal Army has also recently reinstated the Unification Trail (The Nepalese Voice, 2019), which has a historical value. Except these, other historical trails have not been documented either by the DoA or local governments, which suggests the need for massive awareness building alongside feasibility studies on the possible use of such trails in tourism. If the answer is yes, it would require restoration of roadside heritage infrastructures and addition of a new unit under DoA for oversight on historical trails. The mandate of such a trail section could include conservation of historical trails and associated infrastructure such as ponds, paties (traditional shelters for travelers), chautaries (stone paved resting places shaded by Pipal (*Ficus religiosa*) and Banyan (*Ficus benghalensis*) trees. Another area for DoA capacity building is procurement of good and services and administrative and management skills for ensuring timely and at-cost completion of restoration projects.

#### 4.3. Strategies for attracting and retaining the private sector in heritage conservation

The young generation is not attracted towards the heritage sector which has created a paucity of entrepreneurs and artisans (Cozens, 2015). Social recognition

seems to be the major obstacle to getting people to be interested in this area. In addition, there has been very little attention by the government to this area, particularly in terms of skills development and job creation. Changing this would require a focused training center, with adequate facilities and finances. In Nepal, the Small Industries Area Bhaktapur was established for promoting industries on wood carving and other handicrafts. However, the industrial facility has been occupied by other general industries such as painting, dairy industries, etc. (IDM, 2018). The industrial district could have helped artisans to offset costs significantly because they cannot afford to lease private land and buildings. The Maya Foundation has initiated a concept where individual households can have a facility for handicrafts on the ground floor and also be used for residential purposes. Additionally, it is planning to promote homestay at these houses (NRA, 2020a). However, this is a heavily subsidized model, which would be difficult to replicate. Therefore, there is no alternative public intervention for promoting vocational training institutes to impart various skills needed for heritage conservation.

## 5. Conclusions

The DoA inability to deliver its mandated responsibility of conserving monuments and assuring compliance to archeological norms has increased the risk of losing heritage sites and monuments. This study aimed to identify conceptual and institutional constraints resulting in this state of affairs and to recommend ways for effective conservation of all national cultural monuments and sites. The major conclusion of this study is that the DoA's present institutional set up as a subsidiary department under a ministry with other mainstream responsibilities remains the main problem for its inability to attract policy-level attention. Another problem is the AMPA that largely fails to address the heritage conservation challenges. Therefore, it is important to consider either the formation of a Ministry of Culture with heritage conservation as an integral component or to form a new

authority under the Office of Prime Minister and be made responsible for the conservation of heritage monuments, sites and trails. Irrespective of the preferred institutional arrangement, it is imperative that the ANPA 2013 be amended to account for the federated governance structure and the shared responsibilities for different levels of government as mandated by the Constitution. In addition, such an amendment would also need to incorporate heritage research, historical trails, and basic strategies for engaging the private sector in heritage conservation. These measures can contribute towards preventing Nepal's heritage sites from being de-listed UNESCO's list or being downgraded to the "endangered" category.

## References

- [1] Aryal, T., 2019. Bhaktapur sets an example for local-led heritage reconstruction, while Kathmandu and Patan fall short by. *The Kathmandu Post*, 25 April.
- [2] Brush, C., 2019. "God is angry because this is not done": Bungamati residents yearn for the rebuilding of iconic temple. *The Kathmandu Post*, 14 July. <https://kathmandupost.com/valley/2019/07/14/without-machhindranath-temple-bungamati-residents-feel-homeless> (accessed 30 September 2020).
- [3] Chaudhari, C., 2018. Ancient Pond Reconstruction in Kathmandu Stirs Preservation Protests. *Global Voices*. <https://globalvoices.org/2018/01/04/ancient-pond-reconstruction-in-kathmandu-stirs-preservation-protests> (accessed 30 September 2020).
- [4] Cozens, C., 2015. Post-quake Nepal faces shortage of skilled artisans. *Taipei Times*. <https://www.taipeitimes.com/News/biz/archives/2015/11/01/2003631391> (accessed 28 September 2020).
- [5] Dangal, D., 2019. NRA releases fund for rebuilding 190 Sindhupalchowk Gumbas – My Republica - The New York Times Partner, Latest news of Nepal in English, Latest News Articles, My Republica. <https://myrepublica.nagariknetwork.com/news/nra-releases-fund-for-rebuilding-190-sindhupalchowk-gumbas> (accessed 27 September 2020).
- [6] Dawadi, B. K., 2018. Activists warn KMC of taking



- legal remedies against demolition of Bag Durbar. Nepal Republic Media Pvt. Ltd. <https://myrepublica.nagariknetwork.com/news/activists-warn-kmc-of-taking-legal-remedies-against-demolition-of-bag-durbar> (accessed 24 September 2020).
- [7] DDCMS, 2020. DDCMS Updates, Department for Digital, Culture, Media and Sport. <https://www.gov.uk/government/organisations/department-for-digital-culture-media-sport> (accessed 4 April 2020).
- [8] DoA, 2020. Institutional Profile of Department of Archeology, Department of Archeology. <http://doa.gov.np> (accessed 1 April 2020).
- [9] GoN, 1989. Ancient Monuments Preservation Rules 2046. Legal Books Publishing Committee, Government of Nepal, Kathmandu. <http://www.lawcommission.gov.np/en/wp-content/uploads/2018/09/ancient-monuments-preservation-rules-2046-1989.pdf>.
- [10] GoN, 2017a. Ancient Monument Preservation Act 2013. Legal Books Publishing Committee, Kathmandu.
- [11] GoN, 2017b. Constitution of Nepal 2074. Legal Books Publishing Committee, Kathmandu.
- [12] ICOMOS. 1964. International Charter for the Conservation and Restoration of Monuments and Sites; the Venice Charter 1964. Stockholm.
- [13] IDM. 2018. Souvenir of Industrial District Management Ltd., Industrial District Management Ltd. <https://idm.org.np/publications> (accessed 28 September 2020).
- [14] Jing F. et al., 2017. Reactive Monitoring Mission to the Kathmandu Valley (Nepal, C 121BIS). World Heritage Center, ICOMOS, & ICCROM. <http://whc.unesco.org/en/list/121/documents> (accessed 24 September 2020).
- [15] Mahatara, B., 2019. Tourism industry in Nepal: Make it backbone of economy. International Media Network – Nepal Pvt. <https://thehimalayantimes.com/opinion/tourism-industry-in-nepal-make-it-backbone-of-economy> (accessed 29 September 2020).
- [16] MoC-Thailand, 2020. Homepage of Ministry of Culture Thailand. <https://www.m-culture.go.th/en>.
- [17] MoC&T, 2020. Homepage of Ministry of Culture and Tourism of the People's Republic of China, Government of People Republic of China. [http://subsites.chinadaily.com.cn/ministries/tourism/2017-07/21/c\\_85471.htm](http://subsites.chinadaily.com.cn/ministries/tourism/2017-07/21/c_85471.htm) (accessed 4 April 2020).
- [18] MoC, I., 2020. Homepage of Ministry of Culture, India. <http://www.indiaculture.nic.in> (accessed 4 April 2020).
- [19] MoCHA, 2020. Ministry of Cultural Heritage and Activities, Wikipedia. [https://en.wikipedia.org/wiki/Ministry\\_of\\_Cultural\\_Heritage\\_and\\_Activities\\_\(Italy\)](https://en.wikipedia.org/wiki/Ministry_of_Cultural_Heritage_and_Activities_(Italy)) (accessed 4 April 2020).
- [20] NRA, 2019. Ranipokhari reconstruction begins, National Reconstruction Authority. <http://nra.gov.np/en/news/details/nGIXDQxN4IjZ42SL4QPM7VDTqQx-W1Vmzgk-C1l-WJO0> (accessed 28 September 2020).
- [21] NRA, 2020a. Pilanchhe: Model of urban reconstruction, National Reconstruction Authority. <http://www.nra.gov.np/en/news/details/sKDUTCbVa7xRjNtefl9oEL-WBGGboAB3LEUjdT-oUzOQ> (accessed 28 September 2020).
- [22] NRA, 2020b. Reconstruction Update. National Reconstruction Authority (NRA), 4 April. <http://www.nra.gov.np>.
- [23] NRICP, 2016. 2015 Project for International Contribution to Cultural Heritage Protection. Tokyo.
- [24] NS, 2019. Balgopaleshwor to Be-reconstructed in Original Malla Era Granthakut Style, Nepali Sansar. <https://www.nepalisansar.com/culture/balgopaleshwor-to-be-reconstructed-in-original-malla-era-granthakut-style> (accessed 27 September 2020).
- [25] Ojha, A., 2020. Reconstruction of prominent temple inside Kathmandu Durbar Square finally begins. The Kathmandu Post. <https://kathmandupost.com/valley/2018/10/29/mayor-shakya-inaugurates-reconstruction-of-maju-dega-temple-20181029144058> (accessed 30 September 2020).
- [26] Nepal Law Commission, 2015. Constitution of Nepal 2015. Kathmandu, Nepal.
- [27] Poudel, K. P., 2020. Temple Reconstruction Lalitpur Takes Lead. New Spotlight Magazine. <https://www.spotlightnepal.com/2020/02/12/temple-reconstruction-lalitpur-takes-lead> (accessed 30 September 2020).
- [28] Sharma, C., 2017. NEPAL Buddhist monks in Kathmandu streets to protest failure to rebuild quake-damaged monasteries, AsiaNews.It. <http://www.asianews.it/news-en/Buddhist-monks-in-Kathmandu-streets-to-protest-failure-to-rebuild-quake-damaged-monasteries-41400.html> (accessed 27 September 2020).

- [29] Shrestha, C. B. et al., 2010. Trans-Himalayan Heritage Routes in Kailash Sacred Landscape (KSL)-Nepal Area. Kathmandu.
- [30] The Kathmandu Post, 2018. Rani Pokhari blunder. The Kantipur Publications, 28 September.
- [31] THT, 2020. National Reconstruction Authority seeks one-year tenure extension, International Media Network – Nepal Pvt. Ltd. <https://thehimalayantimes.com/business/national-reconstruction-authority-seeks-one-year-tenure-extension> (accessed 30 September 2020).
- [32] TMC, 2018. Rebuilding of Ranipokhari as per design of Department of Archaeology: Mayor Shakya - Tourism Mail, Tourism Mail. <https://www.tourismmail.com/rebuilding-of-ranipokhari-as-per-design-of-department-of-archaeology-mayor-shakya> (accessed 30 September 2020).
- [33] Tuladhar, S. P., 2020. Building back Rani Pokhari even better. Nepali Times. <https://www.nepalitimes.com/banner/building-back-rani-pokhari-even-better> (accessed 29 September 2020).
- [34] UNESCO, 1979. Nepal – UNESCO World Heritage Centre, United Nations Educational, Scientific, Cultural Organisation. <https://whc.unesco.org/en/statesparties/np> (accessed 29 September 2020).
- [35] UNESCO, 2020. Nepal – UNESCO World Heritage Centre, United Nations Educational, Scientific, Cultural Organisation. <https://whc.unesco.org/en/statesparties/np> (accessed 9 September 2020).
- [36] Xinhua News Agency, 2013. Kathmandu’s fate of being listed as endangered heritage site hangs in balance. Global Times. <https://www.globaltimes.cn/content/764660.shtml> (accessed 28 September 2020).



## Comparing Seismic Retrofitting Approaches of Traditional Stone Masonry in Mud Mortar Buildings in Nepal

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*Keywords: retrofitting, stone masonry, mud mortar.*

### Abstract

The 2015 Gorkha, Nepal Earthquake killed more than 8,000 people. Over a million houses were either partially damaged or completely destroyed. According to the Central Bureau of Statistics, 2015/16, 74 percent of the damaged houses were of low strength masonry, such as adobe, and stone masonry in mud mortar (SMM) often found across the mid hills of Nepal. Such low strength non-engineered masonry construction is built using traditional construction practices, with minimal seismic-resistant features, resulting in buildings that are unable to withstand code level earthquake impact. However, retrofitting these buildings has shown to substantially increase their seismic performance, whilst also maintaining the living area of the existing house at a much cheaper cost. This paper investigates the advantages and disadvantages of retrofitting an existing building, rather than constructing a new house within the context of Nepal. From the authors' experience, retrofitting could provide many benefits over new construction and be more widely adopted as long as the implementers understand when retrofitting is a suitable approach.

### 1. Introduction

Retrofitting is a viable option not only for stone masonry in mud mortar (SMM) buildings that are affected by the earthquake, but also as a preventative measure for buildings that are vulnerable to future earthquakes or other natural hazards but have not sustained any damage yet. Following the 2015 Gorkha earthquake, more than 75,000 (Central Bureau of Statistics, 2015/16) houses were considered as partially damaged and categorized as being eligible for retrofitting by the National Reconstruction Authority (NRA) of Nepal. There are approximately 3.5 million SMM houses across Nepal (Central Bureau of Statics,

2011) that require some seismic retrofitting to make them resilient to future earthquakes.

The Government published repair and retrofit manuals cater to the large number of buildings that needed retrofitting within the earthquake affected areas. This manual included four different retrofit designs for SMM buildings. In addition, the Government approved a further 'type design' for SMM buildings and for dry stone masonry (DSM) buildings.

A project funded by the Department for International Development (DFID), led by the United Nations Office for Project Services (UNOPS) supported the construction of 290 retrofits across the earthquake affected districts. Two retrofit approaches for SMM houses were

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adopted as part of this project: the ‘splint and bandage’ approach based on the manual and the ‘strong back’ type design approach. Both retrofitting approaches aim to reduce the structure’s susceptibility to out-of-plane failure, provide confinement to the structure and strengthen the masonry walls. As part of the project, 206 houses were retrofitted using strong back approach. Another 18 houses were retrofitted using the splint and bandage approach and 66 were retrofitted using the ‘timber retrofitting’ method.

This paper presents a critical review of the two retrofitting approaches for SMM buildings and where relevant, it compares them to new construction. The retrofitting approaches are compared across four criteria: constructability, durability, cost and environmental impact.

The comparison is based on experiences of implementing both technologies in the field. The feedback obtained from the design team, the site team, the builders that were involved and the homeowners whose houses were retrofitted is used in this paper. These feedback was compiled over a period of three years. The costs from retrofitting buildings at the sites were used as a basis for calculation of the cost of example buildings. This was important to do as in the case of SMM houses, the walls are not plain, hence, the use of materials for plastering and other construction work could differ from theoretical bill of quantities calculations.

A separate paper (Giordano, 2020) breaks down the two solutions into incremental steps and assesses the return on investment for both approaches. It also provides a comparison of the vulnerability curves for each incremental step.

## 2. Traditional SMM buildings

Stone in mud mortar construction is one of the oldest construction practices in Nepal. The stones are usually mined from the shores of the river or from the rocks extracted from the stone quarries in the mountains. The locals do not have to pay for the stone, but they need to pay for the labor required for extraction and



Figure 1. 3D model of a traditional SMM house

transportation. Depending on the location, the stones used for this kind of construction could vary from dressed, semi-dressed to random rubble stones. The timber used is generally of good quality and found locally.

The traditional SMM buildings are generally two stories, plus an attic. The outer wall layout is rectangular in shape. The low storey height and thick walls in these buildings compensate for the low strength of the masonry itself. These buildings have mud floors that consist of a central timber beam that runs across the center of the floor. The central timber beam also supports the timber joists, that in turn support the mud floor. The central beam is supported by timber posts that occur at approximately the same position on each floor. They eventually continue upwards to support the ridge beam of the roof. At the two extreme ends, the central timber beam is supported by the transverse walls.

There is sometimes a timber band at the floor level but it usually does not continue around the building. The roof is supported by the ridge beam at the center, and the eaves at the other end.

It is generally observed that the joists are well embedded into the walls. In windy area, buildings either use heavy roofing materials like stone or clay tiles, or use light corrugated galvanized iron (CGI) sheets, weighed down with stones or other heavy materials.



Figure 2. An SMM house with a store front in Kavre with large openings at the ground floor



Figure 3. An SMM house without store front Sindhupalchowk

There are generally two major types of SMM houses, built according to their use or location. One type, are houses near market places, where the ground floor is used as a store front and hence has larger openings in the ground floor. The other is a house which is only used for residential purpose and has smaller entrance openings.

These SMM buildings are similar in construction across the mid-hill region of Nepal and therefore demonstrated similar damage patterns following the 2015 earthquake. The damages that were commonly observed in these kinds of buildings are discussed in the following sections:

**Delamination of walls:** The walls in SMM buildings are generally 450mm or thicker. The larger stones are arranged along the two outer faces of the walls and the gap between these two stones are filled with mud and small pebbles. There is generally no through connection between these two outermost wythes. Hence, when there is lateral shaking, the wall behaves as two slender walls instead of one thick wall resulting in delamination of the two layers and eventually leads to collapse.

**Gable wall collapse:** The SMM houses typically have stone masonry gables above the attic walls, which extend all the way up to the roof. There is no positive connection of this wall to the roof and is supported

only by the weight of the roof in normal conditions. During earthquakes, due to the lack of positive connection of these walls to the roof, these walls collapsed. Sometimes, they facilitated the subsequent collapse of the transverse wall below. This was one of the most common damage observed across all the districts.



Figure 4. Collapse of gable walls, sometimes also destabilizes the wall below

**Transverse wall out of plane damages:** Out of plane damages were observed more frequently in transverse walls that extended across. This could be due to the fact that the joists span between the long



Figure 5. Out of plane damage in transverse walls including delamination in attic wall

walls, but the floor is connected to the transverse walls, only with the central beam and is not properly restrained. Hence, we could see the transverse walls had suffered out of plane damages and in some cases the wall had completely pulled out and collapsed.

**Parapet walls out of plane damages:** Since the roof is not resting directly on the parapet walls in the attic, the wall lacks restraint or bracing at the top. In cases where the parapet walls were stout, this was not observed. However, where there were taller attic walls or in case of houses without attic, this type of damage was more common.

**Diaphragm deficiency:** The floor joists in SMM buildings usually rest directly on the walls. The wall plates are often absent to restrain these beams at the edges and act as a tension chord element. Hence, we could observe vertical cracks formed at the floor level in many of these buildings.

### 3. Strong back design approach

The provision of inter-storey wall supports, commonly referred to as “strong-backs”, is commonly used in the United States and New Zealand to increase the out of

plane wall capacity. The role of these columns is not to take gravity loads but only to transfer lateral loads from the walls to the ground. In the Christchurch earthquake, steel strong backs were observed to have performed well where they had been added to a masonry building (Ingham & Griffith, 2011).

The strong back approach is based on the type design approved by the Central Level Project Implementation Unit (CLPIU), Building Division, under the NRA. The design comprises a system of reinforced concrete strong backs placed at corners and at locations along the length of the wall. They are connected at the floor level by slab strips and ring beams at the top of the walls. The strong back is connected to the walls with the help of through anchors. The function of the strong back is to brace the walls out of plane and provide a load path for the out of plane wall loads. The strong backs also act as a buttress to break the horizontal span of the wall and provide connection above and below.

At the floor levels, a slab strip is provided around the inside perimeter of the wall and across, connects opposite strong backs. The function of the slab strip is to improve connectivity of the walls to the diaphragms and to each other, creating a box effect. Also, it is connected to the joists and functions as a chord element at the edge of the diaphragm increasing the diaphragm stiffness and strength. A reinforced concrete ring beam is provided to the top of the walls to provide connectivity and restraint to the walls at the top.

Through concrete is provided at a spacing of 600mm, center to center, all over the walls. The through concrete’s job is to connect the inner and outer wythes of the thick walls preventing them from splitting and hence increasing the overall out of plane capacity of the walls.

Finally, a cement sand plaster is applied to the walls on the internal and external surfaces, to increase the in-plane strength and stiffness of the walls. Heavy gable walls made of SMM is dismantled and a light CGI or timber gable is affixed with good connection to the roof and the ring beam. In addition, improvements to the connections with the existing timber elements are provided with the help of CGI straps.



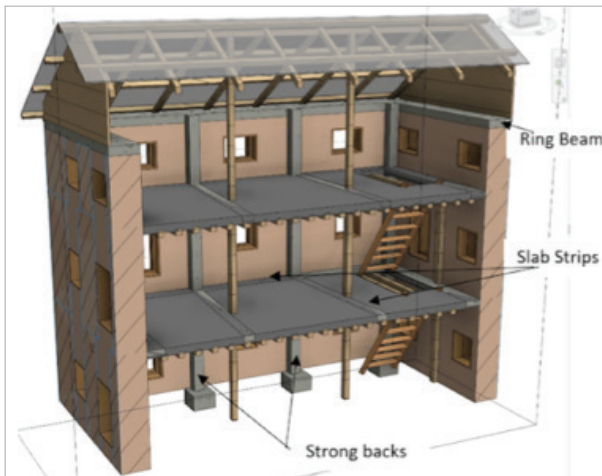


Figure 6. Schematic of strong back approach



Figure 7. House retrofitted with Strong Back approach

#### 4. Splint and bandage design approach using welded galvanized iron (GI) wire mesh

A study of the damage to SMM buildings in Nepal following the 2015 earthquakes found that bands around openings successfully contained and prevented diagonal shear failure of the masonry (Adhikari & D'Ayala, 2019). The National Society for Earthquake Technology-Nepal (NSET, 2012) has performed numerous studies on various versions of splint and bandage and jacketing retrofits for masonry structures in Nepal, including a full-scale pull-down test of retrofitted building. The test was conducted on buildings retrofitted using the jacketing technique. It helped demonstrate that the presence of the wire mesh increases the strength and stiffness of the structure (Shrestha, Pradhan, & Guragain, 2012). Tests by Pun (2015), also showed that wire mesh can effectively increase the strength of SMM buildings, particularly in the lateral span, and potentially improve the ductility of the walls.

Further research was conducted by Kadam (Kadam, 2013) on shearing rigidity, shear strength, drift capacity, and ductility. It was observed that strengthening of unreinforced masonry walls using welded wire mesh (GI wire mesh) results in significant improvement in shear strength and ductility. An increase of up to 7

times in shear strength, and up to 24 times in ductility has been observed for reinforcement ratio of 0.29 percent in both the directions. The strength of the walls were enhanced as a result of the reinforcement.

The splint and bandage approach considered in this paper is based on the Repair and Retrofit manual published by the NRA, 2018.

The splint and bandage design consists of vertical splints, at building corners, wall intersections and on either sides of the openings, and horizontal bandages, at sill, lintel and floor levels. The wall area not covered by the splint and bandages are covered by wire mesh that confines the walls. Galvanized iron wire mesh was used for the splints and bandages. Although there are other options for splint and bandage also mentioned in the Repair and Retrofit Manual such as reinforced concrete, timber, etc., this paper will consider the use of the galvanized iron wire mesh as it was found to be cheaper and more practical to install.

The function of the splints is to add in-plane capacity and stiffness to the walls. The splints at the edge of the piers, provides tension capacity to the walls. The splint comprises galvanized iron wire mesh installed on either side of the wall. The wire mesh installed on the inside and outside of the walls is connected by rebar anchors at regular intervals. The wire mesh thus installed is fixed at the bottom by a plinth beam. The

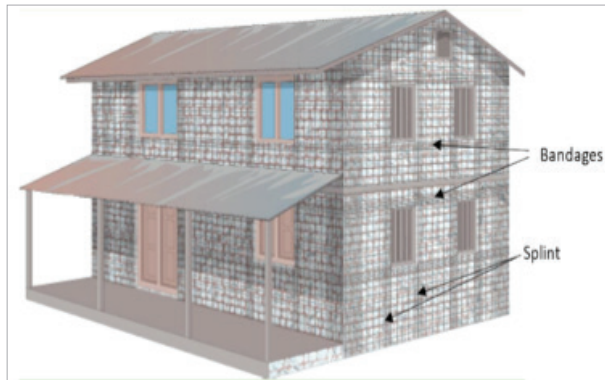


Figure 8. Schematic of splint and bandage approach from the *Repair and Retrofit Manual*



Figure 9. Splint and bandage retrofit of actual house

function of the bandage is to tie the walls together to provide box action. The bandages are similar to splints in terms of materials used but are horizontal instead of vertical.

The function of the plinth beam is to anchor the rebar in the splints, strengthen it and connect it back to the wall foundation. The confining reinforcement consists of a galvanized wire mesh that helps to hold the wall together, in case of shaking during earthquakes, preventing disintegration. The inside and outside confining reinforcement is connected to each other with the help of wire anchors.

Cement sand plaster is applied on the outside and inside of the walls to cover all the reinforcement. The cement sand ratio used in splint and bandage design is richer in cement compared to strong back approach.

Other works such as replacing heavy gables with light, well-connected ones and overall improvement in connection of existing timber members were done similarly.

## 5. Constructability

The SMM houses across Nepal are very similar in terms of their shape, size and structure. However, depending upon the skills of local builders and local construction practices, slight variations do exist. Hence, in these structures the theoretical designs might need to be adapted for site conditions. Some issues have been

identified with both approaches during retrofitting. The details are provided below:

### Condition of existing building

The first step in the construction process for both retrofit methods is to remove the existing mud plaster from all walls – assuming it is present. Site engineers have reported that during this process, large masses of mud mortar is likely to detach from the wall, leaving large voids. This is later filled in with cement slurry or plaster. The quality of masonry in SMM buildings in Nepal is highly inconsistent. Some buildings have good quality masonry characterized by regular blocks, a low mortar-stone ratio, and some have irregular stones but low mortar-stone ratio. However, in some cases the quality of the masonry is extremely poor, with small stones and a very high mortar-stone ratio. The condition of the stone is relevant to the retrofitting approach chosen and the constructability of the retrofit.

### Masonry walls are not always aligned vertically

The masonry walls are not always aligned vertically or horizontally. This can be due to design intentions. For example, the walls might be thicker at the base and the inner face of the wall steps in at each floor, reducing the thickness as you go up the building, or due to poor workmanship.



Figure 10. SMM house with rubble and high mortar-stone ratio



Figure 12. SMM house with angular stones and low mortar-stone ratio



Figure 11. SMM house with shaped stones and low mortar-stone ratio

The strong backs are constructed to be vertical. Therefore, a filler material needs to be added between the strong back and the wall, which increases costs and also adds complexity. For the splint and bandage approach, the wire mesh can be installed to

a non-aligned wall profile. However, extra labor is required to bend the wire mesh, which could increase the cost of intervention.

#### Splicing of existing timber posts

The strongback retrofits require the timber posts supporting the central floor beam to be spliced and continuous to the ring beam, all the way to the attic wall. The timber splicing requires extra timber elements and connections. Sometimes, the timber posts in different floors might not be aligned vertically, which adds additional complexity to the details. These elements are not required in the splint and bandage approach.

#### Installation of wire mesh

The splint and bandage approach requires working with galvanized welded wire mesh, which is difficult to work with, due to the thick diameter of the wires used in the design. This makes construction and installation of splints at corners and at wall stepping sections very difficult and time consuming.

The GI wire mesh on the inside and outside of walls needs to be connected either by anchorage bars or GI wires at regular spacing. However, drilling of GI wires through the wall is difficult due to uneven mud mortar level and multiple wythes of masonry. It is also



difficult to push GI wires through the mortar joint as the wires are not very stiff. In comparison, installing the anchorage bar is easier as the bar can be hammered or pushed into the mortar portion of the masonry.

### Cement Sand Plaster

As the surface of SMM walls can be uneven, it is difficult to apply plaster and that often results in the thickness of the plaster being uneven across the entire surface. Unfortunately, this cannot be avoided, although it can be reduced using trained and experienced masons. The problem is exacerbated when plaster is applied over wire mesh as the gap between the mesh and stones needs to be filled and this often requires two layers which requires more labor and materials.

Based on the field experience, the splint and bandage retrofits end up with an average of 50mm thick plaster on both sides of the wall, whereas the strong back approach has an average thickness of 40mm of plaster.



Figure 13. Application of GI wiremesh in Splint and Bandage retrofit

### Constructability comparison

Workmanship in Nepal can often be of lower quality and therefore requires close supervision by trained engineers who can enforce quality standards. The quality issues detailed above in respect to reinforcement,

concreting and plastering are possible to overcome. They can be improved with the help of engineers and builders who are familiar with improved construction techniques.

Considering the issues described above, and discussions with site engineers who have supervised both strongback and splint and bandage retrofits, there is not one scheme which is the easiest to construct. Masons are generally more accustomed to using rebar and cement rather than wire mesh. However, thorough training can help overcome this. Each approach lends itself to different existing building configurations:

**Splint and bandage approach:** more suitable for straightforward buildings with limited additional walls (e.g. cross walls and buttresses) and for buildings with low quality masonry and needs strengthening.

**Strongback approach:** best suited to larger houses, with multiple walls/cross walls/projections and where the piers are vertically aligned.

### Durability

As the traditional SMM houses are made up of stones, mud mortar and timber, there are some issues regarding the durability of some of the elements used in the construction. Due to interaction of those elements with moisture, rotting can set in. There has been little research carried out or evidence found validating the long-term durability of retrofitting in SMM buildings or for the durability of timber used for construction (Costa, 1979). This section discusses issues that are present in some of the elements that could affect the durability in SMM buildings and ways to mitigate them through retrofitting.

#### Durability of wooden joists, beam and vertical posts

As a natural material, timber is vulnerable to rot and termite attack if left untreated and exposed to damp conditions. In most traditional SMM houses, the timber used is untreated, unseasoned softwood, which has very little natural durability.





Figure 14. Deterioration of timber member at the base



Figure 15. Timber member embedded in cement plastered SMM wall

In the majority of houses the floor rests on wooden joists which are embedded into the masonry wall, where the timber interacts with moisture inside the wall. The timber posts supporting the central floor beam are embedded into the mud floor, sitting on bed stones, and therefore also in contact with moisture.

The major challenge with retrofitting lies in increasing the durability when the existing timber joists are embedded in the masonry wall. It is then covered in cement sand plaster as recommended in either design. The cement sand plaster creates an impermeable layer on either side of the wall which prevents natural evaporation of moisture within the wall. Hence, it keeps the mortar damp, which then interacts with timber making it more susceptible to rot. A solution to this may be to wrap the surface of the embedded timber in a locally available impermeable membrane, such as plastic sheets. The embedded timber can be treated using paint available locally, or varnish.

Periodic change of wooden joists or vertical posts, retreating it by painting or varnishing and reinstalling it also increases the durability of the timber. This would require that part of the existing wall be dismantled to facilitate access. An alternative solution would be to plaster the wall in a more compatible permeable mortar such as lime or mud. These plasters would not provide the required protection to the wire mesh of the splint and bandage, but it could be a suitable option for the strongback.

### Durability of the cement-based plaster

The cement sand plaster acts as an impermeable layer, preventing moisture from evaporating naturally, which leads to the build-up of water between the inner and outer cement plaster. In cold climates, this can be detrimental due to freeze-thaw induced cracking and in warmer climates, it can cause erosion of the mud mortar within the wall.

To limit the erosion induced by the cement sand plaster, finding an alternative more compatible mud or lime plaster could be the solution. However, this is not ideal for the splint and bandage retrofit where the galvanized wire mesh requires additional protection due to the poor quality of the galvanizing. This can be rectified by protecting the mesh by applying bitumen paint (Black Japan) or by improving the production of galvanized wire mesh. In addition to protecting the mesh, further testing would need to be carried out. It would help determine whether the wire mesh can be sturdy enough if covered in a lime or mud-based plaster.

### Durability comparison

The issues associated with durability affect both retrofitting approaches due to the concerns regarding the compatibility of the cement plaster with the mud mortar and timber. It would be more suitable for SMM

buildings to be plastered with a material that does not allow moisture to be trapped inside. However, further research is required to investigate potential materials for both approaches.

### Cost

The total cost of construction for a new building and retrofitting can be broken down into three important categories: building material, labor and transport. For purposes of comparison, transport costs are excluded in this study as they can hugely vary depending on the exact location of the building.

In order to compare the retrofitting costs for each approach, a theoretical SMM two-storey house (8m X 5m) with an attic was considered and all the required material and labor was calculated. This was in turn compared to a new building (6.75m x 6.75m) using Stone Masonry in Cement mortar (SMC), based on designs and Bill of Quantities (BOQs) in the DUDBC design catalogue (Nepal Reconstruction Authority, 2015). The comparison had to be made with an SMC building, since a two-storey with attic building can no longer be constructed using SMM. The rates used for materials and labor are the same across all houses and based on average market rates across different districts.

As the houses are of different sizes, it is more logical to compare the cost in terms of cost per square meter of livable space. This comparison is presented in Figure 18.

The cost comparison between the two retrofitting methodologies was also done based on average cost per square meter of livable space.

As expected, Figure 16 and Figure 17 shows that a new SMC 2.5 house is significantly costlier than a retrofit solution. The cost is almost four times the cost of a splint and bandage retrofit and almost five times the

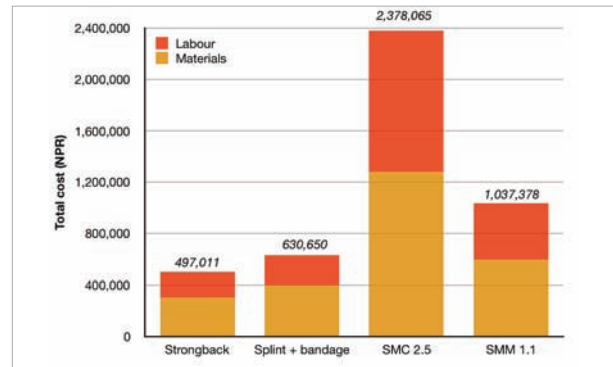


Figure 16. Cost of retrofitted houses compared to the cost of new design catalogue houses

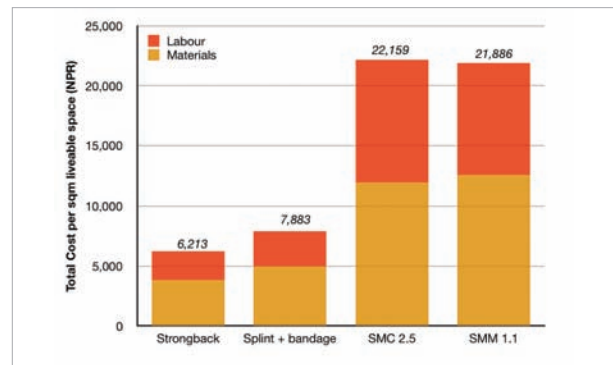


Figure 17. Cost per square meter of livable space for retrofitted home compared with design catalogue homes

cost of the strong back retrofit. Indeed, the strong back retrofit is the cheaper of the two retrofitting options.

### Cost comparison

The cost data presented in this section shows that retrofitting is significantly less expensive than new construction both as a total cost and also per square meter of living space. The two retrofitting approaches are approximately equivalent in cost, with the splint and bandage being slightly more expensive due to the

Retrofitting Methodology	No of houses	Average Area (m2)	Average Cost (per m2)
Strong back	225	74.91	6,012
Splint and Bandage	27	89.56	7,700

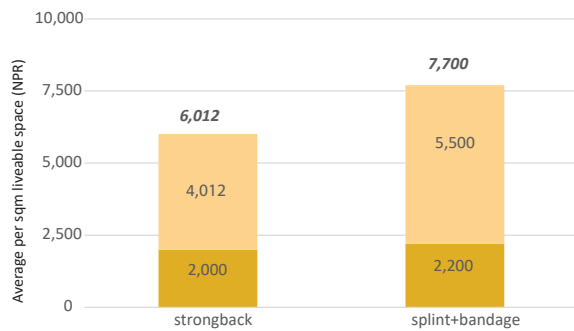


Figure 18. Average cost per square meter livable space of houses retrofitted with the two approaches

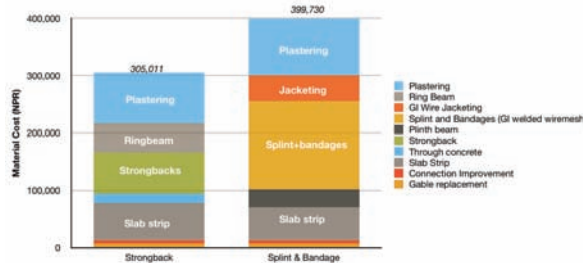


Figure 19. Cost of materials for strong back and splint and bandage solutions

high cost of wire mesh. If this cost could be reduced, then the difference would be marginal.

A large portion of the retrofitting cost depends on the amount of cement used. Further research should be done on the possibility of reducing the quantity of cement or replacing the concrete members with non-cementitious material (e.g. lime based plaster)

### Environmental impact

The construction industry is one of the largest global contributors to emissions of greenhouse gases, so it is vital to consider the sustainability of the retrofitting options. There is a wide range of performance indicators that can be used to measure sustainability within the construction industry (Kamali & Hewage, 2015), but within the scope of this research, only environmental criteria are considered.

Global warming potential (GWP) will be used as an indicator to compare the environmental impact of

strong back, splint and bandage, and new construction. GWP is a measure that enables comparison of the global warming impact of different gasses. It is defined as the amount of energy that one ton of a gas will absorb over a given time, relative to one ton of carbon dioxide (USEPA, 2017). The GWP values used in the comparison, have been obtained from the database of construction materials developed for India (IFC, 2017), which is thought to be the most relevant data for Nepal. Gaps in information have been filled using the Inventory of Carbon and Energy (ICE) database (Jones & Hammond, 2019), which although developed for the UK market, has a much wider range of materials. Since the Indian database assumed carbon capture for wood and other natural materials, the GWP values for timber have been obtained from the ICE database. Stones and mud have been assumed to be sourced locally and to have zero GWP.

It is assumed that Green House gases produced during construction are low to negligible due to an absence of machinery on-site and that carbon emissions throughout the life of the building are negligible, as most homes do not use electronic items. Transport of materials to site has not been considered in this analysis. It should however be noted that the transport of materials has the potential to be a significant contributor to emissions, especially when materials can't be sourced locally.

Figure 20 presents the results of the GWP analysis broken down by constituent materials. The most significant contribution to GWP is due to the presence of

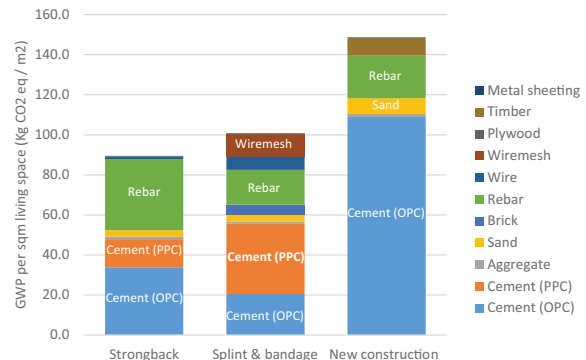


Figure 20. GWP for each retrofitting technique

cement. Note that Portland Pozzolana Cement (PPC) (cement with 15-25% of fly ash) is used for the plastering. Ordinary Portland Cement (OPC) is used for all other concrete elements (e.g. ring beam, foundation improvement, slab strip, strong backs and cement mortar in SMC home). Comparing the two retrofits, the materials required for the splint and bandage has a higher GWP than those for the strong back. The primary reason for this is the plaster, which is significantly thicker than the kind used for the strong back and has a higher proportion of cement compared to sand. However, both retrofits produce approximately 60 percent of the GWP. For the SMC structure the GWP due to cement alone is significantly higher than both retrofits in their entirety.

### Environmental impact comparison

Retrofitting has an approximately 60% lower environmental impact, compared to a new SMC structure. Between the two retrofits, the splint and bandage has a higher GWP due to the greater thickness of plaster and higher proportion of cement used.

As the cement plaster has a very high environment impact, a key area for further research would be to investigate alternative options for plastering the wall that reduce or omit cement. Further research is also recommended to investigate other options for the mesh in the splint and bandage system, or make use of recycled materials.

## 6. Conclusion and recommendation

Retrofitting is a viable option to preserve traditional architectural heritage in the community and to maintain the living space that is required for agrarian life. However, it is a relatively new approach in Nepal, which makes scaling of the technology nationwide challenging. The challenges include clear government policy, creating awareness among the home owners, capacitating government and private sector engineers, enhancing skills of local masons and availability of tools and materials.

Based on the experience of implementing both approaches, each one has its advantages and lends itself to a particular situation.

In the splint and bandage approach the wire mesh acts to constrain the stone walls, and is therefore more suitable for buildings where the masonry is of lower quality. However, it is used in straight forward buildings where there are limited internal walls, buttress walls or external projections, as these increase the cost and complexity of construction. There can also be difficulties obtaining the wire mesh in rural markets and this might impact the overall cost of construction.

The strong back approach is best suited to larger houses, with multiple walls, cross walls and projections. Cost and/or global warming potential is a significant factor for the homeowner. This approach is more suitable in cases where the piers are vertically aligned as this leads to reduced intervention and cost.

In comparison to constructing a new house, retrofitting is a much more cost effective and environmentally friendly solution. It is also a more pragmatic approach for the general population. However, the cost of retrofitting is still higher than what homeowners are willing to invest to improve their houses. Therefore it is necessary to either produce alternative, cheaper, approaches or come up with financing schemes that can make retrofitting more affordable to homeowners. This would be key in enabling the scaling of retrofitting across Nepal.

Both the Government approved retrofitting options available are heavily based on iron and cement, neither of which are local materials. More research should be done to developing retrofitting options using timber or bamboo. More research into using an alternative to plaster also needs to be looked into.

Most importantly, a long-term approach to making retrofitting more affordable to the wider population is required. Incremental retrofitting breaks down the two existing retrofitting approaches into distinct phases, addressing primary deficiencies first and then addressing other deficiencies in the following phases. This could reduce the barrier to finance and encourage more homeowners to retrofit their homes.



Additional research needs to be done to quantify the risk reduction, and to assess the cost benefit that would be attained by each phase of retrofitting for both of these approaches. Further study also needs to be done to identify how these phases of retrofitting can be incentivized to interest more homeowners.

## References

- [1] Adhikari, R. K., & D'Ayala, D., 2019. 2015 Nepal Earthquake: Seismic Performance and Post-Earthquake Reconstruction of Stone Masonry Buildings. EEFIT.
- [2] Authority, N. R., 2017. Repair and Retrofit Manual for Masonry Structure. Government of Nepal, Kathmandu.
- [3] Build Change, 2015. Build Change Post-Disaster Reconnaissance Report, April 25. Gorkha Earthquake, Nepal.
- [4] Central Bureau of Statics. 2011. National Housing and Population Census. National Planning Secretariat. Government of Nepal, Kathmandu.
- [5] Central Bureau of Statistics, 2015/16. CBS Damage Survey, Nepal.
- [6] Costa, D., 1979. Comparative decay resistance of Australian timbers in accelerated laboratory tests.
- [7] Giordano, N., 2020. Life-Cycle Analysis of Incremental Seismic Retrofitting of Traditional Constructions in Nepal .
- [8] IFC, 2017. India Construction Materials Database of Embodied Energy and Global Environmental Indicators for Materials Warming Potential Methodology & Results Methodology Report. IFC.
- [9] Ingham, J. M., & Griffith, M. C., 2011. The Performance of Earthquake Strengthened URM Buildings in the Christchurch CBD in the 22 February 2011 Earthquake. Addendum Report to the Royal Commission of Inquiry. <https://pdfs.semanticscholar.org/034f/24f-dd654712790596b38b5c89094435f5deb.pdf>.
- [10] Jones, C., & Hammond, G., 2019. Circular Ecology. Retrieved December 5. <http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html#.Xg10li0Q3OQ>.
- [11] Kadam, 2013. Strengthening of unreinforced masonry using welded wire mesh and micro-concrete – Behaviour under in-plane action.
- [12] Kamali, M., & Hewage, K. N., 2015. Performance indicators for sustainability assessment of buildings. 5th International/11th Construction Specialty Conference. Vancouver.
- [13] Nepal Reconstruction Authority, 2015. Design Catalogue for Reconstruction of Earthquake Resistant Houses - Volume I. Government of Nepal, Kathmandu.
- [14] Pun, R., 2015. Improvement in Seismic Performance of Stone Masonry Using Galvanized Steel Wire. University of Technology, Sydney.
- [15] Shrestha, H. et al., 2012. Experiences on Retrofitting of Low Strength Masonry Buildings by Different Retrofitting Techniques in Nepal. 15WCEE. Lisbon.
- [16] USEPA, 2017. Understanding Global Warming Potentials, February 24, retrieved December 30, 2019. <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>.



## Cost-Benefit Analysis of Incremental Seismic Retrofitting of Traditional Constructions in Nepal

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*Keywords: retrofitting, incremental, stone masonry mud mortar, cost-benefit analysis.*

### Abstract

In the 2015 Gorkha, Nepal earthquake, over one million buildings were destroyed or damaged, of which more than 50 percent were traditional stone in mud mortar (SMM) unreinforced masonry (URM) constructions. Empirical evidence from several geographical contexts has shown that URMs have minimal seismic-resistant features. However, adequate retrofitting interventions can substantially increase their seismic performance. The economic cost of retrofitting remains an issue and often prevents building owners and investors from retrofitting their buildings in advance of the next earthquake. This paper investigates the potential for utilizing incremental retrofitting strategies in Nepal, to allow owners to retrofit their buildings in a gradual and cost-effective way. Two main retrofitting approaches for SMMs are broken down into phases, each of which is analyzed to quantify the structural improvement to the building. A probabilistic cost-benefit analysis of each phase is carried out to assess the return on investment of seismic enhancement. Results indicate that retrofitting is a financially advantageous investment since the reduction in future earthquake-induced loss largely exceeds the upfront cost of the intervention. Additionally, the incremental approach allows more flexibility in allocating resources and could increase the appeal of retrofitting as a risk mitigation measure.

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## 1. Introduction

Seismic retrofitting is considered one of the most effective techniques for earthquake risk reduction. Past seismic events in Nepal and worldwide have shown that retrofitted constructions are not only safer for the occupants but also less prone to damage (Sorrentino and Cattari 2019). In an earthquake, the majority of the economic loss comes from physical damage (Guettiche et al. 2017). Therefore, the implementation of retrofitting interventions at scale can limit disproportionate impacts on the economy when a disaster strikes. This is particularly valid for seismically active regions where traditional non-engineered unreinforced masonry (URM) constructions represent the vast majority of the total building stock. Empirical evidence has shown that URMs are characterized by numerous structural deficiencies that negatively affect their seismic response. To name a few: low mechanical properties of masonry material, poor construction quality, lack of wall-to-wall/wall-to-floor connections, absence of seismic detailing (Benedetti et al. 1998). In Nepal, where more than 60 percent of the inventory is URMs (Central Bureau of Statistics 2011), the average annual loss of the residential portfolio estimated by the Global Earthquake Model (Pagani et al. 2014) is about US\$ 400 million. This is roughly 0.36 percent of the asset replacement cost, consistently higher than the average 0.11 percent of the world's top 16 earthquake affected countries.

Despite this, there are barriers to seismic retrofitting (Nuti and Vanzi 2003). First, structural interventions represent an important upfront investment for building owners, that can be up to 60 percent of the replacement cost of the building (Liel and Deierlein 2013). Second, such interventions are usually invasive (involve the removal of non-structural components and finishing) and disruptive (require temporary relocation of the building occupants). Third, building owners and investors are usually uncertain about the benefit of retrofitting that is projected into a distant and unforeseeable future. That said, the financial cost of disasters is eventually paid by governments that have to cope

with disproportionate losses given the large number of unretrofitted buildings. Therefore, from a regulator perspective, it is crucial to incentivize retrofitting before a major earthquake strikes.

Mechanisms to incentivize seismic retrofitting have been discussed since the nineties (Federal Emergency Management Agency 1994) and nowadays are an integral part of disaster risk reduction programs in several countries. A common characteristic of these policies is that older buildings are not required to perform at the same level of new constructions. On the contrary, partial retrofitting interventions are allowed, aimed at an improvement of the original capacity of the structure. In this way, the limited available resources for risk mitigation can be distributed over a larger number of constructions, to homogeneously increase the resilience of the building stock. For instance, with the California Residential Mitigation Program (California Earthquake Authority 2011), homeowners of vulnerable houses constructed before 1979 can apply for a grant of US\$ 3,000 to bolt down the building and brace the cripple walls with plywood, to prevent collapse or sliding off its foundation. New Zealand is also following an approach based on partial retrofitting, where the Building Amendment Act 2016 requires commercial building owners to strengthen their properties up to at least 34 percent of the most recent building standard. Additionally, it provides incentives for retrofitting historical listed buildings (Filippova and Noy 2020). One of the most innovative seismic retrofitting policy was released by the Italian Government in 2017. The Sisma Bonus Act (Ministero delle Infrastrutture e dei Trasporti 2017) supports residential and commercial building owners to invest in the seismic enhancement of their properties, thanks to tax deductions of up to 85 percent of the total retrofitting cost. To access the tax relief, the owner must file a structural report that quantifies the seismic performance of the building, before and after the intervention. In detail, the performance is expressed in the form of eight risk classes from G to A+, where A/A+ corresponds to the performance of a new building. A tax deduction of 70-75 percent applies

when the retrofit results in an improvement of one class; the contribution can be raised up to 80-85 percent if the intervention generates an improvement of two or more classes. An important aspect of this regulation is that the credit from the tax deductions can be directly transferred from the building owner to the construction company that executes the work. More recently, as part of the financial stimulus in response to the Covid-19 crisis, the Italian Government is trying to boost the construction sector by increasing the tax relief to 110 percent of the retrofitting cost (Government of Italy 2020).

## 2. Objectives of research

Starting from these considerations, this work discusses the retrofitting of traditional Nepali SMM buildings and tries to answer two important questions: (i) what is the Return on Investment (ROI) of retrofitting traditional stone-masonry buildings? (ii) Can standard retrofitting approaches be subdivided in incremental steps to spread the upfront investment over a longer time? Section 3 describes the two retrofitting technologies currently approved by the National Reconstruction Authority (NRA) and the incremental subdivision of these interventions. Section 4 discusses the structural vulnerability of the incremental steps and presents the cost-benefit assessment methodology adopted in the study. Lastly, Section 5 includes the discussion of the results in terms of ROI of retrofitting.

## 3. Retrofitting approaches in Nepal

In response to the 2015 earthquake event, the Government of Nepal, through the NRA, has reviewed and approved two seismic retrofitting approaches for traditional masonry houses. Under the Government of Nepal housing reconstruction program, homeowners of partially damaged buildings can access a grant of NRs. 100,000 to retrofit their homes (National Reconstruction Authority 2017). These two approaches, namely the Strongback (STB) and the Splint and Bandage (S&B), are described in the following subsections.

### 3.1 Strongback (STB)

The STB system (Figure 1a), developed by Build Change, is designed using the Nepal Building code NBC105:1994 (Department of Urban Development and Building Construction 1994). The STB retrofit refers to the addition of vertical reinforced concrete (RC) braces, or STBs, at the corners and at regular centers along the internal face of the masonry wall. These STBs are connected to the wall using RC “through-ties”, which aim to facilitate transfer of seismic forces between the wall and the STBs, as well as reduce the separation of the multi-leaf wall. The RC elements play an important role in tying the walls back to the floors, providing a load path for the out-of-plane wall loads to reach the diaphragms above and below. The installation of STBs to prevent the out-of-plane action of URM walls is an established practice for typical brick masonry buildings in the United States and has been identified as a standard retrofitting technique in FEMA 547 (Federal Emergency Management Agency 2006) and FEMA P-774 (Applied Technology Council 2009). At floor level, a 100mm thick RC slab strip is provided around the perimeter and at two interior cross tie locations. The strips are supported vertically on the floor joists and pinned to the STBs and building walls. The objective of the slab strip is to improve the wall-to-floor connections and to increase the diaphragm action. At the eaves level, a 150mm deep RC ring beam is provided, with a width equal to the thickness of the wall. The roof rafters are tied to the ring beam via metal straps embedded in the concrete, and L-bars are provided to connect the STBs to the ring beam. The heavy masonry gable is removed and replaced with a lighter corrugated iron one and the connections within the roof structure are improved. As a final step, the building walls are covered internally and externally in a cement-based plaster. The general implementation procedure for the STB is: 1) site clearance/fixing of scaffolding/removal of existing plaster; 2) repair of cracks /placement of through concrete; 3) construction of ring beam; 4) construction of foundation for strongback; 5) construction of strongback and connection

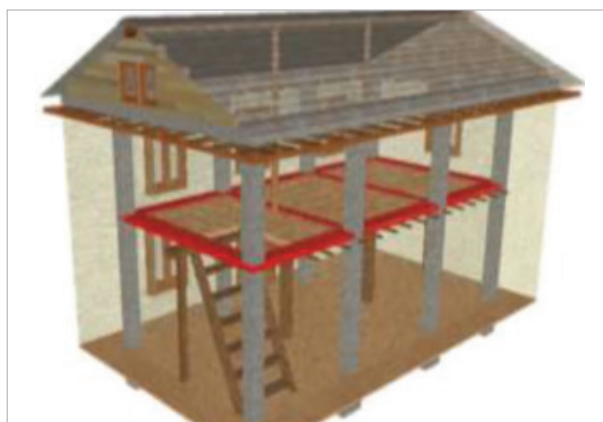


to walls with dowels; 6) construction of slab strips; 7) plastering; 8) roof connection improvement.

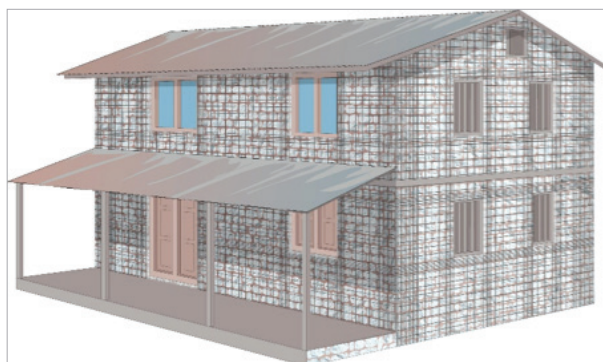
The STB approach has not undergone a full-scale shaking-table or pushover test, however, it refers to a number of experimental tests on the effectiveness of the constituent elements: experimental shear-compression tests on SMM piers with and without cement plaster (Build Change 2018) to estimate shear and drift capacity at element level; vertical and diagonal compression tests on SMM samples to investigate the influence of stabilized soil plaster, cement-based plaster and through-ties on material's shear strength and stiffness (Build Change 2016; Build Change 2019); compression tests of stones from the mid-hills of Nepal (Build Change 2015).

### 3.2 Splint and Bandage (S&B)

The S&B method of retrofitting masonry buildings is designed according to NBC105:1994 (Department of Urban Development and Building Construction 1994) and is based on providing horizontal and vertical strip elements at critical locations of the structure such as corners, wall intersections, openings, floor/roof-to-wall junctions, etc. (Figure 1b). This enhances the seismic performance of masonry walls improving in plane response and reducing localized out-of-plane failures. In Nepal, one of the first introductions of this technique was done in 1999 when, as a pilot of the School Earthquake Safety Program (SESP), the National Society for Earthquake Technology – Nepal (NSET) implemented the retrofitting of Bhuwaneshwory Lower Secondary School at Bhaktapur using this method (Asian Disaster Preparedness Center 2003). The vertical (splint) and horizontal (bandage) elements provided along both the outside and inside surface of the load bearing walls are designed considering both in-plane and out-of-plane behavior. In case of low strength masonry, Galvanized Iron (GI) wire mesh is additionally provided at other locations of the walls to prevent local failure and spalling of masonry units. Through wires or semi through connectors are provided on the walls at certain intervals in a staggered



(a)



(b)

Figure 1. Retrofitting strategies in Nepal: (a) Strongback (STB), (b) Splint and Bandage (S&B)

fashion to tie the inner and outer meshes together in all locations of the wall. Depending on the design and various other factors, either rebars or welded wire mesh can be used as reinforcement encased in a (1:1.5:3) concrete layer of 40mm thickness or plaster. When rebars are used as reinforcing elements, micro concrete (with aggregates less than 10mm in size) is adopted. Rich 1:3 cement plaster is applied when wire meshes are employed as reinforcement. The application of concrete or plaster is solely manual, and hence applied in two layers. For the outer surface of walls, both the welded wire mesh and GI wires are provided with a plaster layer of 30mm thickness, while 20mm of plaster is provided on the interior surface. The GI mesh is comprised of wires which is usually placed further

apart than those in the welded wire meshes, according to design. Reinforcing elements of the splints along with the vertical GI wires are tied to the floors and to an anchorage/tie beam at the base of the building. A wider tie beam is provided when rebars are used for the splints. The general process of implementation of retrofitting work using steel wire mesh includes: 1) Removal of existing plaster from walls in the proposed area 2) Raking out mortar joints to 15-25 mm depth, air cleaning and wetting the surface 3) Excavating the soil for tie beam and laying the reinforcement 4) Applying the wire mesh on walls and providing anchor rods or through wires to tie inner and outer wire mesh firmly with the wall 5) Anchoring the wire mesh to the rebar of the tie beam 6) Concreting the tie beam 7) Applying plaster to the wall 8) Curing.

Over the last years, several versions of the S&B method have undergone full scale experimental tests (Shrestha et al. 2012; Bothara et al. 2019) that have validated the good seismic performance of the technique. Additionally, empirical evidence after the 2015 earthquake has shown that almost all buildings (mainly schools) retrofitted with the S&B technique, whether in areas of low or high ground shaking during the event, performed very well (NSET 2015, Wang et al. 2018).

### 3.3. Incremental retrofitting subdivision

To allow partial and incremental interventions, herein the STB and S&B approaches are broken down into a number of discrete retrofitting elements which are then assembled into phases or steps (Table 1). In Phase 1, both techniques include the substitution of the masonry gable with a light weight corrugated galvanized iron (CGI) sheet and the improvement of roof connections. In addition to these two measures, Phase 1 of STB includes the casting of the RC ring beam to the top of the walls (subsequently connected to the vertical frame elements) and the installation of RC through-ties. While Phase 1 of S&B includes the construction of the roof band with welded wire mesh, Phase 2 represents the most demanding part of the incremental retrofitting since it involves the construction of the RC elements (STB) and the realization of the splints and bandages (S&B). From a structural point of view, Phase 2 corresponds to a consistent upgrade of the building’s seismic response. Thanks to the new connecting elements, wall-to-wall and wall-to-floor connections are consistently improved and the building can respond in a box-like manner under seismic loads (Giordano et al. 2020). Therefore, Phase 2 represents the turning point

Table 1 - Incremental phases of retrofitting for STB and S&B approaches

	STB	S&B
Phase 1	<ul style="list-style-type: none"> <li>◊ Replace stone gable with a light weight CGI sheet</li> <li>◊ Improve the connections of roofing members</li> <li>◊ Cast a ring beam to the top of the walls</li> <li>◊ Install RC through-ties in the walls</li> </ul>	<ul style="list-style-type: none"> <li>◊ Replace stone gable with a light weight CGI sheet</li> <li>◊ Improve the connections of roofing members</li> <li>◊ Construct a roof band with welded wire mesh</li> </ul>
Phase 2	<ul style="list-style-type: none"> <li>◊ Install vertical reinforced concrete strong backs</li> <li>◊ Install reinforced concrete slab strips at floor levels</li> </ul>	<ul style="list-style-type: none"> <li>◊ Construct splints and bandages</li> <li>◊ Improve floor action*</li> </ul>
Phase 3	<ul style="list-style-type: none"> <li>◊ Apply cement-based plaster on the external and internal faces of the walls</li> </ul>	<ul style="list-style-type: none"> <li>◊ Jacketing with wire mesh</li> <li>◊ Apply cement-based plaster on the external and internal faces of the walls</li> </ul>
* floor-to-wall connections and/or floor diaphragm strengthening depending on solution		

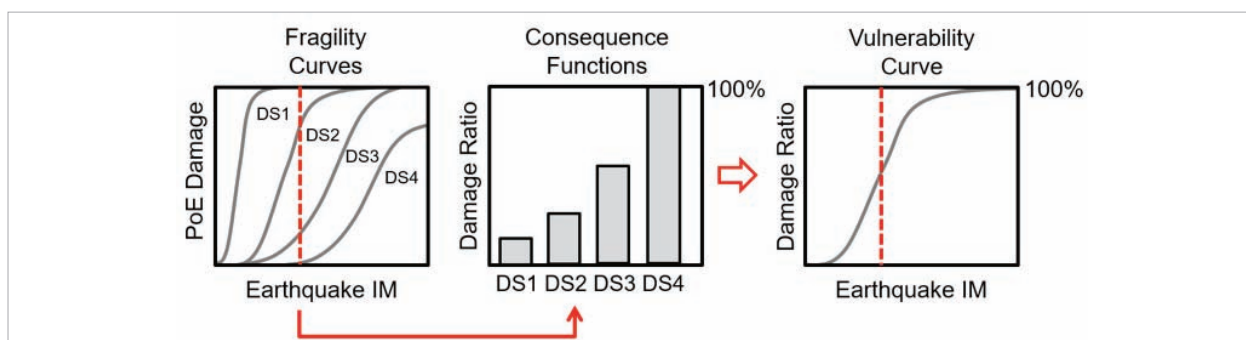


Figure 2. Derivation of vulnerability curves from damage fragilities and consequence functions (PoE = Probability of Exceedance)

from predominant out-of-plane damage to in-plane damage. The last step of the incremental processes consists in the plastering work. For STB it involves the use of cement based plaster while for S&B it also includes wire mesh reinforcement.

#### 4. Cost-benefit assessment methodology

The cost-benefit analysis is carried out considering a nominal life of the SMM-URM building equal to 30 years (Department of Urban Development and Building Construction 1994). The analysis is performed with reference to an archetype index building characterized by: two stories, average interstory height of 2.1 m, average in plan shape of 4 m × 8 m, average wall thickness of 0.5 m. Retrofitting benefit (B) can be quantified in different ways; however a common measure to estimate mitigation measures is in terms of reduction in future Expected Annual Loss (EAL) before and after the application of the retrofit (Liel and Deierlein 2013; Giordano et al. 2018). Similarly, the cost (C) can be annualized to quantify the ROI = B/C (De Risi et al. 2018). The ROI can be directly used as a decision-making tool: if ROI is larger than one, the mitigation measure is in fact financially advantageous.

##### 4.1. Vulnerability assessment and benefit quantification

The first step to quantify the benefit of a retrofitting measure consists of calculating the vulnerability curve

of the structure before and after the intervention. In this work, vulnerability curves are estimated for the original building and at each retrofitting phase. A building's vulnerability function correlates a representative Intensity Measure (IM) of the earthquake (such as the Peak Ground Acceleration, PGA), with the repair to replacement cost damage ratio. Vulnerability curves can be derived from damage fragility curves through consequence functions (Figure 2) (Rossetto et al. 2014) where: (i) fragility curves are probability of exceedance functions of damage states (DS), and (ii) consequence functions express the repair to replacement cost ratio of each DS.

In this work the fragility curves are calculated using the analytical model developed by Giordano et al. (2019) where four damage states are considered: DS1 - slight damage, DS2 - moderate damage, DS3 - severe damage, DS4 - near collapse. This method considers the in-plane and out-of-plane damage potential depending on the characteristics of the building. A fully probabilistic Monte Carlo approach is adopted to derive fragilities where random variation of mechanical parameters, geometry and seismic record are directly taken into account. In the absence of specific consequence functions for Nepali SMM buildings, HAZUS relationships are adopted (Federal Emergency Management Agency 2015). Figure 3 reports the vulnerability results of the two retrofitting approaches (STB and S&B) for each incremental phase. The effect of structural interventions has been directly taken into account by modifying the input parameter of the fragility model according



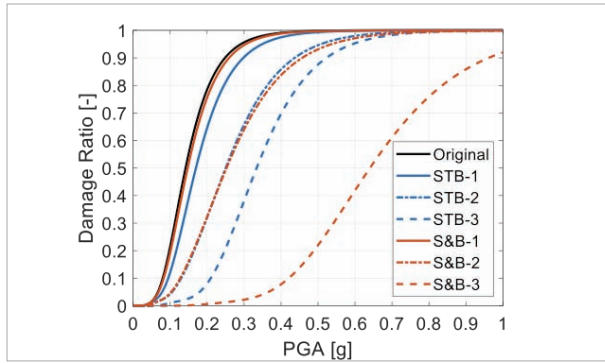


Figure 3. Vulnerability curves for different retrofitting solutions and incremental phases

to experimental tests and literature studies (de Felice 2011; Kadam et al. 2015; Wang et al. 2018).

The vulnerability results show that:

- Phase 1 of both approaches provides a slight decrease of vulnerability with respect to the original structure since it refers to limited interventions, such as the gable replacement. Phase 1 of STB provides a larger reduction of vulnerability given the presence of RC through-ties.
- Phase 2 generates a consistent increase of seismic capacity for both STB and S&B solutions. As previously mentioned, the building does not respond as a system of loosely connected walls but as a ‘box-like’ structure. The out-of-plane damage is now limited to the portion of walls between adjacent STB or S&B. Consequently, the in-plane failure mode becomes the critical one.
- The last phase corresponds to the code-compliant retrofitting solution currently approved by the NRA. Even though it is not fully consistent to compare design results with vulnerability results (in the first case the assessment is carried out deterministically rather than probabilistically), it is observed that for both techniques the damage ratio at Peak Ground Acceleration,  $PGA = 0.3 \text{ g}$  is lower than 50 percent. This ground intensity level corresponds to the PGA that is used to design for life safety for a SMM house with nominal life equal to 30 years. Additionally, 50 percent damage

ratio is generally considered equivalent to the life safety limit state (Federal Emergency Management Agency 2015). Lastly, it is noted that Phase 3 of the S&B approach provides a consistent increase of seismic capacity given the presence of the steel wire mesh. In fact, the reinforcement acts as additional protection against in-plane and out-of-plane damage.

From the vulnerability curves the benefit of each retrofitting step is estimated through the Expected Annual Loss EAL with the following equation (Porter 2018):

$$EAL = V \int_0^{\infty} y(s) \frac{-dG(s)}{ds} ds \quad (1)$$

Where  $G(s)$  represents the hazard, i.e. the mean annual rate of exceedance of PGA as for Stevens et al. (2018),  $V$  is the replacement cost of the building,  $y(s)$  is the vulnerability curve. The benefit of a given retrofitting phase is calculated as the difference between the EAL before and after mitigation:

$$B = \left( V \int_0^{\infty} y(s) \frac{-dG(s)}{ds} ds - V_m \int_0^{\infty} y_m(s) \frac{-dG(s)}{ds} ds \right) \left( \frac{1-e^{-\rho t}}{\rho} \right) \quad (2)$$

where  $V_m$  and  $Y_m$  refer to the retrofitted building,  $\rho$  is the real discount rate assumed equal to 7 percent for Nepal (CIA 2017) and  $t = 30$  years is the planning period. In this study, the replacement cost of the building has been considered constant and equal to NRs. 10,123,000.

## 4.2. Cost quantification

The cost estimation of the index building has been carried out by NSET and Build Change. NSET has gained experience through the years on the S&B technique by retrofitting and providing technical assistance to over 300 buildings, including 56 buildings in the recent Baliyo Ghar Project. Build Change has enhanced its global experience through implementing and providing technical assistance to 332 STB and 18 S&B retrofits in Nepal. Three retrofitting cost estimates are provided in this work: one for the STB approach and two for

the S&B approach. It should be noted that fluctuation in construction costs is generally high in Nepal and largely affected by building geometry, local availability of materials, cost of the workmanship and transportation. Table 2 reports the breakdown of the costs with respect to the incremental steps.

Once the initial costs are estimated, they are annualized for a consistent comparison with the EAL reduction. The following equation is adopted (De Risi et al. 2018):

$$C = C_m \cdot \frac{\rho}{1-(1+\rho)^{-t}} \quad (3)$$

where  $C_m$  is the upfront cost of the retrofitting intervention.

## 5. Discussion of the results

The last step of the analysis is the estimation of the return on investment  $ROI = B/C$ . In Figure 4 the results are reported. The green bars correspond to the total ROI of the retrofitting phases with respect to the original configuration. The light blue bars refer to the relative ROI between consecutive incremental steps. It is noted that the S&B solution reports multiple values of the ROI since two cost estimates are available.

On average, both retrofitting techniques provide a total ROI larger than four i.e. every dollar spent in

retrofitting pays back four dollars over the thirty-year lifetime of the building. This also implies that retrofitting investments are paid back in less than seven years. This result largely justifies investments in retrofitting traditional SMM masonry constructions in Nepal. The incremental ROI is always larger than four meaning that the subdivision in phases is well-balanced in terms of costs and benefits. In general, it is observed that the lower bound of ROIs of S&B is roughly equivalent to the values available for STB.

As expected, Phase 1 provides the lowest ROI. This is because some of the interventions cannot be taken into account in the fragility model (e.g. the connections of roofing members).

Variation in retrofitting costs represent an important factor when assessing the ROI as it is observed from the S&B results. Interestingly, large fluctuation in costs do not change the outcome of the analysis and still demonstrates the effectiveness of retrofitting.

## 6. Conclusion

In Nepal, the earthquake risk remains one of the major threats to the safety of the population and the stability of the economy. For this reason, it is imperative to focus resources on mitigation measures. Experiences from other seismic prone-countries show that retrofitting policies have been strongly promoted to improve the overall performance of the building stock when

Table 2 - Cumulative cost of incremental retrofitting phases

	STB1,*	S&B2,*	S&B3,*
Phase 1 ['000' NRs.]	162	61	32
Phase 2 ['000' NRs.]	326	279	148
Phase 3 ['000' NRs.] (total cost)	445	517	273
1 estimate of a 2 story building. Calculation executed with data/costing sheets developed from experience gained in retrofitting 332 buildings			
2 estimate of a 2 story building. Calculation executed with data/costing sheets developed from experience gained in retrofitting 18 buildings			
3 estimate of a 2 story building. Calculation executed with data/costing sheets developed from experience gained in retrofitting 300 buildings			
* Note: the estimates provided in this table have not been validated by an independent third-party			

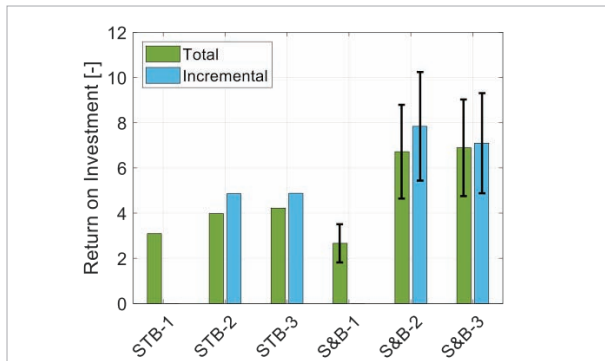


Figure 4. ROI for different retrofitting solutions and incremental phases

subjected to an earthquake event. A safer building stock decreases the risk of fatalities and generates lower direct or indirect economic losses. Additionally, it allows more knowledge, to incorporate financial resilience mechanisms like catastrophe insurance. Partial and incremental retrofitting is nowadays commonly accepted since it allows more flexible risk management actions. It also guarantees a homogeneous distribution of the interventions over the building stock. In this study, a probabilistic cost-benefit analysis has shown that every dollar in retrofitting pays back more than four times over the lifespan of unreinforced stone masonry buildings in Nepal. This means that Governments, supported by donors, could increase resilience in line with the Sendai goals and receive a higher return on their investment. Another important aspect is that current retrofitting technologies can be split into different intervention phases. Thus, retrofitting works can be carried out gradually when financial resources become available. This result represents an important outcome for policy makers and international organizations interested in financing risk reduction programs in the context of Nepal.

## Acknowledgements

This work was funded by the Engineering and Physical Science Research Council (EPSRC) under the project, “Seismic Safety and Resilience of Schools in Nepal” SAFER (EP/P028926/1) and by United Nations Office for Project Services (UNOPS), under the DFID funded project “Seismic Retrofitting of Unsafe Rural Housing in Nepal”.

## References

- [1] Applied Technology Council, 2009. FEMA P-774: Unreinforced Masonry Buildings and Earthquakes. Developing successful risk reduction programs. Washington, DC, USA.
- [2] Asian Disaster Preparedness Center, 2003. The School Earthquake Safety Program in Kathmandu Valley. Bangkok, Thailand.
- [3] Benedetti D. et al., 1998. Shaking table tests on 24 simple masonry buildings. *Earthquake Engineering and Structural Dynamics*. 27, 67–90.
- [4] Bothara, J. et al., 2019. Experimental seismic testing of semi-reinforced stone masonry building in mud mortar, in: 2019 Pacific Conference on Earthquake Engineering. Auckland, NZ.
- [5] Build Change, 2015. Compressive strength of stone blocks (internal report). Kathmandu, Nepal.
- [6] Build Change, 2016. Diagonal and compressive test of specimens made of Stone in Mud Mortar (internal report). Kathmandu, Nepal.
- [7] Build Change, 2019. Diagonal Compression Tests on Stone Masonry in Mud Mortar Samples and Retrofitted Samples (internal document). Kathmandu, Nepal.
- [8] Build Change, 2018. Laboratory Test Report: Combined Axial and Cyclic Shear test on Stone Masonry in Mud Mortar (internal report). Kathmandu, Nepal.
- [9] California Earthquake Authority, 2011. California Residential Mitigation Program - Earthquake Brace + Bolt: Funds to Strengthen Your Foundation. <https://www.quakeretrofits.com>.
- [10] Central Bureau of Statistics, 2011. National population and housing census. Kathmandu, Nepal.

- [11] CIA, 2017. Central Bank Discount Rate. <https://www.cia.gov/library/publications>.
- [12] Department of Urban Development and Building Construction, 1994. Nepal National Building Code. Kathmandu, Nepal.
- [13] Federal Emergency Management Agency, 1994. FEMA 254 - Seismic Retrofit Incentive Programs. Washington, DC, USA.
- [14] Federal Emergency Management Agency, 2006. FEMA 547 - Techniques for the Seismic Rehabilitation of Existing Buildings. Washington, DC, USA.
- [15] Federal Emergency Management Agency, 2015. Hazus-MH 2.1: Technical Manual. FEMA.
- [16] de Felice, G., 2011. Out-of-Plane Seismic Capacity of Masonry Depending on Wall Section Morphology. *International Journal of Architectural Heritage*. 5, 466–482.
- [17] Filippova, O. and Noy, I., 2020. Earthquake-strengthening policy for commercial buildings in small-town New Zealand. *Disasters*. 44, 179–204.
- [18] Giordano, N. et al., 2018. Cost-benefit analysis for the retrofit of masonry buildings through performance-based seismic assessment, in 10th International Masonry Conference. Milan, Italy.
- [19] Giordano, N. et al., 2019. Derivation of fragility curves for URM school buildings in Nepal, in: 13th International Conference on Applications of Statistics and Probability in Civil Engineering, ICASP13. Seoul, South Korea, pp. 1–8.
- [20] Giordano, N. et al., 2020. Out-of-plane closed-form solution for the seismic assessment of unreinforced masonry schools in Nepal. *Engineering Structures*. 203, 109548.
- [21] Government of Italy, 2020. Decree-Law May 19th 2020 (in Italian). Rome.
- [22] Guettiche A. et al., 2017. Economic and Human Loss Empirical Models for Earthquakes in the Mediterranean Region, with Particular Focus on Algeria. *International Journal of Disaster Risk Science*. 8, 415–434.
- [23] Kadam, S.B. et al., 2015. Out-of-plane behaviour of unreinforced masonry strengthened using ferrocement overlay. *Materials and Structures*. 48, 3187–3203.
- [24] Liel, A.B. and Deierlein, G.G., 2013. Cost-Benefit Evaluation of Seismic Risk Mitigation Alternatives for Older Concrete Frame Buildings. *Earthquake Spectra*. 29, 1391–1411.
- [25] Ministero delle Infrastrutture e dei Trasporti, 2017. Decreto ministeriale numero 65 del 07/03/2017 - Sisma Bonus. Rome, Italy.
- [26] National Reconstruction Authority, 2017. Repair and Retrofitting Manual for Masonry Structure. Kathmandu, Nepal.
- [27] National Society for Earthquake Technology – Nepal (NSET), 2015. Final Report on Post Earthquake Rapid Damage Assessment of School Buildings. Kathmandu.
- [28] Nuti, C. and Vanzi, I., 2003. To retrofit or not to retrofit? *Engineering Structures*. 25, 701–711.
- [29] Pagani, M. et al., 2014. Openquake engine: An open hazard (and risk) software for the global earthquake model. *Seismological Research Letters*. 85, 692–702.
- [30] Porter, K., 2018. A Beginner's Guide to Fragility, Vulnerability and Risk. University of Colorado Boulder, USA.
- [31] De Risi, R. et al., 2018. Life Cycle Cost and Return on Investment as complementary decision variables for urban flood risk management in developing countries. *International Journal of Disaster Risk Reduction*. 28, 88–106.
- [32] Rossetto, T. et al., 2014. Guidelines for the empirical vulnerability assessment. GEM Technical Report. 08, 140.
- [33] Shrestha, H. et al., 2012. Experiences on Retrofitting of Low Strength Masonry Buildings by Different Retrofitting Techniques in Nepal, in: 15th World Conference on Earthquake Engineering. Lisbon, Portugal.
- [34] Sorrentino, L., & Cattari, S., 2019. Seismic behaviour of ordinary masonry buildings during the 2016 central Italy earthquakes. *Bulletin of Earthquake Engineering*. 17, 5583–5607.
- [35] Stevens, V.L. et al., 2018. Probabilistic Seismic Hazard Assessment of Nepal. *Bulletin of the Seismological Society of America*. 108, 3488–3510.
- [36] Wang, M. et al., 2018. In-plane cyclic tests of seismic retrofits of rubble-stone masonry walls. *Bulletin of Earthquake Engineering*. 16, 1941–1959.





# Safety of Masonry Infills against Out-of-Plane Failure in Reinforced Concrete Buildings and a Case Study of Community Housing Resettlement Project in Dhading District, Nepal

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*Keywords: Earthquake, in-plane, out-of-plane, reinforced concrete buildings, unreinforced masonry infill.*

## Abstract

Reinforced concrete (RC) frame buildings with unreinforced masonry (URM) infills are used worldwide. During earthquakes, masonry infills in such structures can suffer damages both in-plane (IP) and out-of-plane (OOP) directions, and the OOP collapse of infill walls is a major problem even in new buildings designed to resist earthquake forces. Design codes have recommended measures to prevent OOP failure of infill walls, which, however, are still neglected in new RC constructions due to practical difficulties. This paper aims to highlight the issue of structural safety of masonry infills against OOP failure, discusses practical difficulties in implementing the provisions of the design code, and suggests strategies for compliance. Additionally, the paper presents typical technical challenges faced during the construction of RC buildings especially in the context of rural housings, drawing from experience in reconstruction from a community housing resettlement project in Dhola, Dhading District, which was built for 55 families displaced by 2015 Gorkha, Nepal earthquake. The methodology adopted included review and analysis of available literature, project data and construction practices. The recommendation includes techniques to construct horizontal RC bands, highlighting the necessity of quality workmanship, for improving OOP performance of infill walls.

## 1. Introduction

Building with reinforced concrete (RC) frames are used all over the world and is also popular in Nepal. In these types of buildings, unreinforced masonry (URM) is generally used to construct infill walls. The performance of such buildings during an earthquake depends on the performance of masonry infills, which is largely dependent on how they are arranged in the plan and elevation. Presence of regularly distributed

infills can contribute to the strength and the stiffness and on the contrary, irregular arrangements of infills either in plan or in elevation can have adverse effects (Shing and Mehrabi, 2002; Decanini et al. 2014). Post-earthquake damage surveys after 2009 L'Aquila, Italy earthquake (Ricci et al., 2011) and the 2011 Lorca, Spain earthquake (De Luca et al., 2014) have revealed failure of structures related to the failure of infill walls, which was also observed in 2015 Gorkha, Nepal earthquake. A report published by

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the Government of Nepal estimated that about 6,613 RC frame buildings collapsed and about 16,971 were damaged in the series of earthquakes that occurred in 2015 (NPC, 2015). However, most of the collapsed structures were non-engineered or had been built by following prescriptive design guidelines like Nepal Building Codes NBC 201 (1994b) and NBC 205 (1994c), also known as mandatory rules of thumb (MRT) in Nepal. New RC buildings (low-rise to medium-rise), primarily with moment-resisting frame structures for residential, commercial and institutional uses (government offices, hospitals or university buildings), and some medium to high-rise (10 to 20 stories) apartment buildings in Kathmandu valley, suffered minimum structural damage but had significant infills-related non-structural damage (Murakami et al., 2015; Gautam and Chaulagain, 2016; Barbosa et al., 2017; Varum et al., 2017; Bhagat et al., 2018).

Masonry infills are intended to be non-structural, but since they are built, in contact with the RC frame, they significantly affect the structural earthquake response of the infilled frames and ultimately the whole building. Past research, especially in-plane behavior, of infill walls, has established how they influence strength and stiffness of the infilled frame and how they can be the cause of brittle shear failures of columns, which can lead to a partial or total collapse of buildings during earthquakes. To addressing this, seismic design criteria for the safety of infilled frames have been recommended in design codes and guidelines (e.g. FEMA 306, 1998; NBC 201, 1994b; Eurocode 8, 2004). However, during earthquakes, infill walls are subjected to simultaneous in-plane (IP) and out-of-plane OOP loads, in which large inter-story drifts are expected at lower stories while higher inertia forces are expected at the upper levels. This leads to the failure of URM infills in both IP and OOP directions. Specifically, OOP collapse of infills has been observed in the bottom to mid stories and it is critical even for new buildings designed to withstand earthquake forces as it can result in high number of casualties and economic losses. It was also observed in the 2015 Gorkha, Nepal earthquake (Barbosa et al., 2017; Varum et al., 2017). Therefore, safety against the

OOP failure of masonry infills remains a concern for researchers.

Research on OOP behavior of infill walls is still very limited. Studies have shown that masonry can have adequate lateral strength against OOP loads due to resistance derived from arching action (Dawe and Seah, 1989; Angel, 1994; Flanagan and Bennett, 1999a; Furtado et al., 2016). But OOP resistance of infill walls can be influenced by several factors such as boundary condition between infill and frame (Di Domenico et al., 2018; Butenweg et al., 2019), slenderness ratio (Flanagan and Bennett, 1999b; Ricci et al., 2018; Koutas and Bournas, 2019), aspect ratio (Varela-Rivera et al., 2012a; Moreno-Herera et al., 2016), openings (Dawe and Seah, 1989; Akhouni et al., 2016), gravity load (Varela-Rivera et al., 2012b; Furtado et al. 2016), IP damage (Angel, 1994; Calvi and Bolognini, 2001; Hak et al., 2014; Ricci et al., 2018) to name few. Analytical models have been proposed to estimate the OOP capacity of the URM infill walls (e.g. Dawe and Seah, 1989; Angel, 1994; Bashandy et al., 1995; Flanagan and Bennett, 1999b) and some of them have been adopted in design guidelines (e.g. FEMA 356). However, the reliability of the analytical models is still an open question and numerical modeling techniques to account for OOP behavior of infill wall by considering IP interaction are in initial stages of development (Hashemi and Mosalam, 2007; Furtado et al., 2015; Di Trapani et al., 2018; Nasiri and Liu, 2019; Cavaleri et al., 2019, Pradhan et al., 2020). Besides, to reduce the OOP vulnerability seen in existing masonry infills, research is also underway to replace traditional infills with innovative masonry infill systems (Petrus et al., 2015; Preti et al., 2015; Silva et al., 2016; Verlati et al., 2016; Vailati et al., 2017). For example, Preti et al. (2015) proposed masonry infill with sliding joints while in Vailati et al. (2017), masonry blocks were connected through joints made of recycled plastics rather than conventional mortar. There is, therefore, no fixed approach for determining the OOP behavior of infill walls.

At this stage, there are limited provisions in design codes and guidelines to maintain OOP stability of URM masonry infill walls. The recommendations range from

limiting the slenderness ratio of the infills to making RC bands (Eurocode 8, 2004; FEMA 356, 2000; NBC 201, 1994b). However, there are practical challenges in tying RC bands in infill walls with the columns. Following the devastating earthquake of 2015, the trend of constructing RC frame buildings has increased in Nepal. Inspection of some construction sites has revealed that the RC bands are not constructed properly. Additionally, there are other technical challenges workers face while constructing RC buildings with seismic-resistant features, especially in rural areas of Nepal where there are shortages of skilled workers (Sharma et al. 2018).

This paper aims to highlight the issue of OOP failure of masonry infills in new RC buildings considering the effect it can have in future earthquakes. It discusses the provisions in the design codes and the challenges of compliance. Further, the paper shows the existing practice in RC band construction in Nepal. In the absence of practical guidelines to construct such bands, this paper also demonstrates simple ways in which it can be done. One technique is discussed by presenting a case study of a community housing resettlement project in Dhola, Dhading where RC frame buildings were built for 55 families displaced by the 2015 Gorkha, Nepal earthquake. Besides the provision of horizontal bands, effective workmanship can enhance OOP capacity of masonry infills. Using the resettlement project as an example, this paper discusses simple strategies that are described alongside the technical challenges in the construction of RC buildings, particularly in the context of rural housing in Nepal.

## 2. Methodology

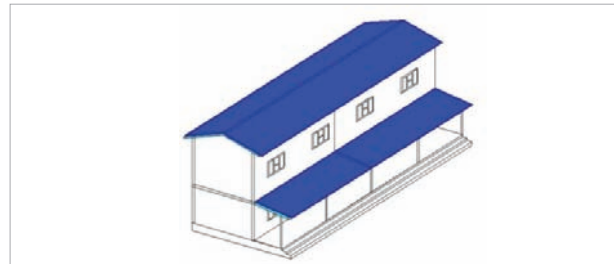
The paper is based on the review of literature on masonry infills especially those considering their performance in OOP loads during an earthquake. The available literature clarified existing knowledge on the topic explained why the OOP failure of infill walls is critical, and what provisions are there in the design codes. Design data and construction details of the resettlement project in Dhading have been used

to describe the challenges of RC construction, especially in the context of rural housing. The analysis is supported by observations from different construction sites. Information was obtained from engineers, contractors, workers and house owners, to understand issues related to RC band construction in Nepal, especially why the bands are neglected during construction to recommend practical strategies.

## 3. Description of the community housing resettlement project

2015 Gorkha, Nepal earthquake rendered a community of people homeless after their houses were completely destroyed. New buildings with masonry infilled RC frame technology were planned, designed and constructed for 55 families as a part of a resettlement project in Dhola-7, Dhading. The project site is remote but connected to Dhading Besi, headquarter of Dhading District.

A sample house that was planned for the people affected by the earthquake is shown in Figure 1. It is a



a. Planned view



b. Constructed at site

Figure 1. 3D view of building

two-story residential building, planned to accommodate two families. Each family would have two rooms on the ground floor and two rooms on the top floor. Two houses were separate in terms of use but were connected for minimizing the cost of construction by sharing wall, footing and frame elements. In case of a single-family house, wherever necessary (due to an odd number of families, the shape of the land, etc.), half the size of this plan with two rooms on the ground floor and two above with the same design, were built. Most of the houses belonged to the first category planned for two families.

The overall height of the buildings to the top of the roof is 20 feet with the ground floor height, 9 feet. The building was covered with a double-sloped lightweight roof. Corrugated galvanized iron (CGI) sheets were

used as a roof cover. The primary width of the building was 13.5 ft. and the length was 44 ft (Figure 2). The building is regular in plan and elevation. The buildings were designed as Moment Resisting RC Frame structures. RC slab (100 mm thick) was used on the ground floor while no RC slab was used on the first floor. Instead, only ring beams were used to tie the columns together (Figure 3).

The buildings were designed with a strong column-weak beam philosophy in compliance with the Nepal Building code (NBC 105, 1994a) as well as the Indian standard, IS 19893 (2002). The seismic zone considered for the design was zone V as per IS 1893 (2002). Tie beams were provided in the foundation and near the ground level. The tie beam was 230 mm x 230 mm and three 12 mm bars were provided at the top and bottom as longitudinal reinforcement while 8 mm stirrups were provided at 150 mm c/c as transverse reinforcement. Square columns of size 300 mm x 300 mm were used in all buildings and each column had four 16 mm rebar and four 12 mm rebar as longitudinal reinforcement and 4-legged 8 mm ties placed at a spacing of 100 mm c/c as transverse reinforcement. Beams in the ground floor had a width of 230 mm and a depth of 330 mm. The longitudinal reinforcements for ground floor beams were composed of two 16 mm bars and one 12 mm bar, and 2-legged 8mm stirrups were provided as transverse reinforcements. The ring beam used on the first floor was 230 mm wide and 200 mm deep and three 12 mm bars were provided at the top and bottom. Light tubular steel sections were provided to support the roof. M20 concrete and FE 500 (TMT) reinforcement bars with a yield strength of 500 MPa were used.

Infill walls were distributed regularly in plan and elevation. Masonry infills were built with solid clay brick with mortar made of cement and sand in the ratio of 1:4. The thickness of all external and internal infill walls was kept 115 mm i.e., the width of a brick, which is smaller than that recommended by the Nepal Building Code (NBC 201, 1994b) in case of an external wall. This increased the need to provide measures to prevent OOP failure during earthquakes.

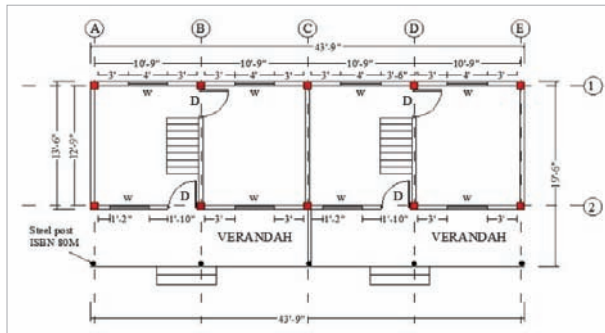


Figure 2. Ground floor plan for building (dimension in feet-inch)

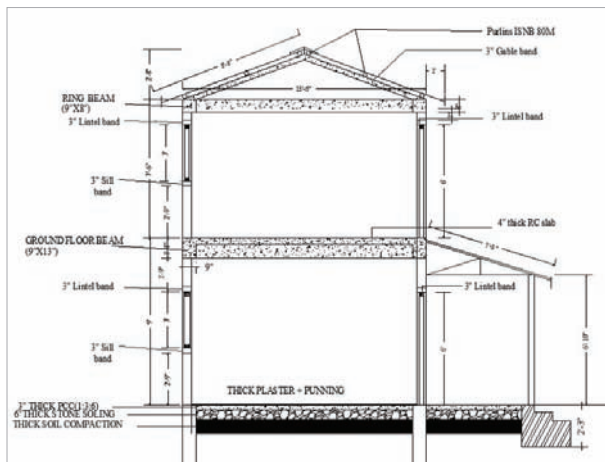


Figure 3. Sectional view of the planned building



The thickness of the infill wall was chosen by the community to reduce the cost as the buildings were to be built with minimum finances. Plaster, with cement sand ratio 1:4, was applied only on the interior faces of infill walls, and walls were not plastered externally, again, to minimize the cost of construction (Figure 1). RC bands of 75 mm thickness were recommended in design drawings at the level of sill and lintel of windows, to reduce OOP vulnerability of the slender infill walls (slenderness ratio was about 21). The RC bands were used even though the community was reluctant to have them owing to technical difficulties associated with construction and also due to the delay that it could cause in the construction of infill walls and subsequently the houses. People had been living in temporary shelters for a long and they wanted to shift to the new buildings as early as possible. The project was, therefore, more need-based and driven by economic considerations rather than by purely technical and safety requirements.

### 3.1 Challenges during the construction of RC buildings with masonry infills

Construction of the houses began a few months after the earthquake of April 2015. Construction was done by using only workers from the community that would be living in the buildings. This was primarily done to lower the cost of construction and it was a major challenge for the consulting engineers. Only a few semi-skilled workers were available in the workforce and even these people lacked the technical knowledge required for building a good house. Additionally, the terrain was difficult and there were issues related to a lack of equipment for excavation during the foundation works. The workers faced difficulties in leveling the ground for making a good foundation for the buildings. Men and women who had very basic construction skills were trained at the site. The construction was started on one building to allow those with minimal skills to learn from observation. This also allowed technicians to support semi-skilled workers to improve their skills. The approach was replicated and eventually, the

process was scaled up to construct all remaining buildings as this was crucial for the timely completion. The construction of all buildings was completed within 18 months. Some of the major technical challenges faced by the workers during the construction were:

1. Leveling off the ground level and foundation pits (due to lack of mechanical tools)
2. Bar bending and the making of stirrups
3. Executing reinforcement details (especially in the beam-column joint)
4. Controlling the quality of concrete mix (maintaining ratio of aggregates and water content)
5. Concrete casting in column (e.g. vibration and compaction issues), and
6. Construction of RC bands and their connections to the frames

All the areas above required special attention from the supervising engineer. The problems were resolved systematically during construction, in accordance with the guidance from the civil site engineer and instructions of structural engineer. The technical issues listed above have often been discussed at different forums but the problem in the construction of RC bands rarely received attention. Even though it might appear simple, there are several things that require consideration while building the bands because care has to be taken to avoid any damage to the columns. Therefore, the construction focused not only on the RC bands but also on the overall workmanship of infill walls. Since the gaps between the infills and frame play a big role in OOP performance of URM infills, it was necessary to maintain tight contact between the frame and infill around the perimeter of the infill wall. It is generally difficult to fulfill this requirement, specially at the interface between the infill and top beam. This problem was addressed by casting the layer of top brick after allowing some days for the hardening of the lower brick layers. This reduced the chances of gap formation due to shrinkage of mortar, a simple technique that workers can adopt once they are trained



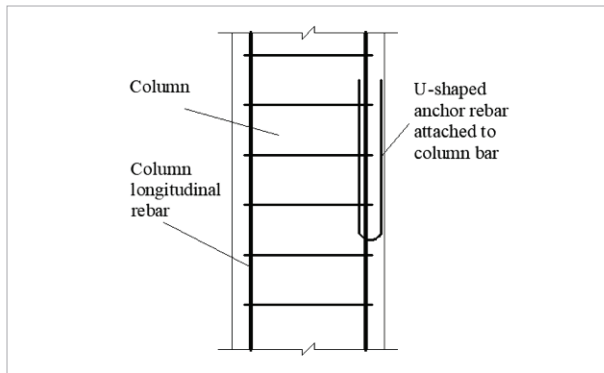


Figure 5. Arrangement of anchor rebar for RC band

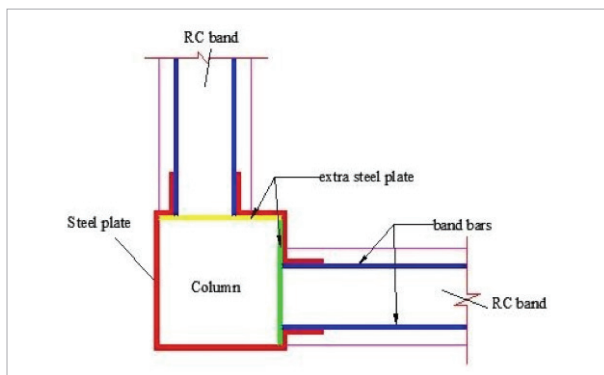


Figure 6. Steel plate as an anchor for RC band

column. The concrete is cast as usual. After removing the formwork, the face of the column where the U-bar sits is scratched to remove concrete carefully. After the concrete cures and gains strength, the outer leg of the U-bar is stretched outside at a right angle to the inner leg and is connected to the longitudinal reinforcement of the lintel or sill band. This method is very sensitive and requires proper care as the extra bars disturb vibration during concreting, increasing the chances of compromising the column strength. Further, the scour depth has to be controlled while removing the concrete because this concrete cover in the column has an important role. Later, the removed concrete needs to be replaced with concrete of similar or higher strength made with small-sized aggregates. Due care is required because replaced concrete will not be like the original concrete as compaction of concrete is difficult to achieve.

d. Method 4: As an alternative to Method 3, columns can be wrapped with steel plates of small width (e.g. 50 mm) and thickness (e.g. 5 mm) as shown in Figure 6. The steel plate is then welded to the reinforcement of the RC bands. Later, steel plates can be covered with high-strength plaster. This technique is quite simple and there is no danger of damage to the columns. The reliability of this method, however, is questionable, considering that the welding between the steel plates and with the reinforcement of RC bands can be damaged by the cyclic nature of earthquake loads. Nevertheless, the infill wall will have higher OOP strength compared to that when the RC band is not connected with the columns.

Both the Department of Urban Development and Building Construction (DUDBC) and the United Nations Development Programme (UNDP) in Nepal recommend Method 3 and 4 as 'safe building practice', although they do not provide detailed construction approaches. The descriptions provided above can thus be expected to be of assistance to construction engineers. Among the alternatives, Method 3 was adopted in the resettlement project in Dhola, Dhading. The approach was selected for the comparative ease, economy and the applicability among different considerations. While building, the RC bands were installed in a way ensuring minimum impact on the columns.

## 5. Construction practices of RC bands in Nepal

Inspection of various construction sites in Nepal revealed different practices used in constructing RC horizontal bands in masonry infill. Based on information on the practices collected from house owners, contractors, masons and engineers, there were three ways in which RC bands were built: no band, bands but not connected to frame, and bands connected to the frame.

1. No band – Some buildings were built without RC bands in infill walls. House owners had no idea why contractors did not build them. Some contractors said the bands delayed their work. RC band construction requires following a step-wise process

infill-band-infill-band-infill that takes more time compared to building infill walls without bands.

2. Bands but not connected to frame – Many houses had RC bands at two levels i.e. sill and lintel but they were not connected to the columns. Many contractors, masons and engineers said they faced practical difficulties in connecting the bands with columns.

3. Bands connected to frame – In some houses, RC bands were connected to columns as suggested in Method 3 above, by inserting U-shaped rebar. In a few cases, the removed concrete portion had been later patched with normal plaster instead of concrete.

In many houses, RC bands were connected to the column partially by drilling the column to about a depth of 2 inches. Reinforcement of the bands was inserted to that depth and grouted using a normal cement-sand mix. Although these types of RC bands can be effective in IP load of the earthquake, i.e., to control diagonal cracking of infill walls, they have little contribution to OOP strength. This technique can be improved with the use of epoxy-based grouting material as described in Method 2 above.

Based on the investigation of several new, infilled frame, RC building construction, it is apparent that infill walls are still built without RC bands or without the proper connection to the frames. This makes infills in new RC buildings vulnerable to OOP failure during earthquakes. This is even more relevant for interior partition walls that are normally constructed with a small thickness.

## 6. Conclusions and recommendations

RC buildings are a popular form of construction and URM infills are important elements of RC frame structures. Such infill walls are highly vulnerable during earthquakes and the OOP failure of infill walls is a risk even for new buildings designed to withstand earthquake forces. Therefore, OOP failure of URM infills remains a concern for researchers.

The practice of constructing RC buildings with URM infills has been increasing in Nepal. But as observations

at the new RC constructions show, the horizontal RC bands are not provided in infill walls as recommended by the design codes. This has resulted because many construction workers remain unaware of how to build the bands. This has increased the risk of OOP failure of infill walls in newly constructed RC buildings during future earthquakes and that could result in both economic losses and human casualties.

The design codes do not provide clear guidelines to construct RC bands in infill walls. Simple techniques can be applied to build the RC horizontal bands in infill walls, which have been discussed in this article. One of the techniques was applied in one reconstruction project and that showed that the method can be used with the proper guidance of the workers. Since making of RC bands is important for risk reduction, they are required to be prioritized alongside the construction guidelines.

Finally, the construction of RC buildings requires a certain level of technical competency among workers. The quality of work can be compromised when workers do not have the required skills and this is true not only for RC elements like beams and columns but also for masonry infills whose OOP performance during earthquakes is greatly influenced by the nature of workmanship. This has created a big challenge for good construction in rural Nepal which has been demonstrated in this article using case examples from a reconstruction project in Dhading District. The paper has also discussed the problems resulting from a shortage of trained workers, lack of access to construction equipment, and the difficulties faced by workers in rebar detailing and concreting. The experience with the project has been discussed to show how workers can be simultaneously trained on-site to make up for the need for skilled workers (especially after a major disaster like an earthquake) for ensuring timely completion of projects. Overall, the need to train construction workers on new construction techniques and on the uses of materials and tools are important for ensuring good quality construction.



## Acknowledgements

The authors are grateful for the financial support provided by Nepal Share that had allowed them to provide technical services to the resettlement project. The authors also thank members of Lapa Earthquake Victim Resettlement Committee in Dhading who had provided support to the technical team members during the supervision and training periods.

## References

- [1] Angel, R., 1994. Behavior of reinforced concrete frames with masonry infill walls. (Doctoral Dissertation) University of Illinois, Urbana-Champaign, IL.
- [2] Barbosa, A.R. et al., 2017. Performance of medium-to-high rise reinforced concrete frame buildings with masonry infill in the 2015 Gorkha, Nepal, Earthquake. *Earthquake Spectra*. 33 (S1) S197–S218.
- [3] Bashandy, T. et al., 1995. Evaluation and analytical verification of infilled frame test data. P.M. Ferguson Struct. Engrg. Laboratory, Report No. 95-1. Department of Civil Engineering, Uni. of Texas at Austin, Austin, Tx.
- [4] Bhagat, S. et al. 2018. Damage to cultural heritage structures and buildings due to the 2015 Nepal Gorkha earthquake. *J. Earthq. Eng.* 22, 1861–1880.
- [5] Butenweg, C. et al., 2019. Experimental results of reinforced concrete frames with masonry infills under combined quasi-static in-plane and out-of-plane seismic loading. *Bull. Earthq. Eng.* 17, 3397–3422, 2019.
- [6] Calvi, G.M., & Bolognini, D., 2001. Seismic response of reinforced concrete frames infilled with weakly reinforced masonry panels. *Journal of Earthquake Engineering*. 5, 153-185.
- [7] Cavaleri, L. et al., 2019. Residual out-of-plane capacity of infills damaged by in-plane cyclic loads. *Eng. Struct.* 109957.
- [8] Dawe, J., & Seah, C., 1989. Out-of-plane resistance of concrete masonry infilled panels. *Canadian J. Civ. Eng.* 16, 854–864.
- [9] De Luca et al., 2014. The structural role played by masonry infills on RC building performances after the 2011 Lorca, Spain, earthquake. *Bull. Earthq. Eng.* 12, 1999–2026.
- [10] Di Domenico et al., 2018. Experimental assessment of the influence of boundary conditions on the out-of-plane response of unreinforced masonry infill walls. *J. Earthq. Eng.* 1–39.
- [11] Di Trapani F. et al., 2018. A macro-element model for in-plane and out-of-plane responses of masonry infills in frame structures. *J. Struct. Eng.* 144 (2), 04017198.
- [12] Eurocode 8, 2004. Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings. European Committee for Standardisation, 1998-1. CEN, Brussels, Belgium.
- [13] FEMA 306, 1998. Evaluation of concrete damaged concrete and masonry wall buildings. Federal Emergency Management Agency. Washington DC, USA.
- [14] FEMA 356, 2000. Prestandard and commentary for the seismic rehabilitation of buildings. Federal Emergency Management Agency. Washington DC, USA.
- [15] Flanagan, R.D., & Bennett, R.M., 1999a. Arching of masonry infilled frames: Comparison of analytical methods. *Practice Periodical on Structural Design and Construction*, . 4(3), 105-110.
- [16] Flanagan, R.D., & Bennett, R.M., 1999b. Bidirectional behavior of structural clay tile infilled frames. *J. Struct. Eng.* 125:3(236), 236–244.
- [17] Furtado A. et al., 2015. Simplified macro-model for infill masonry walls considering the out-of-plane behaviour. *J. Earthq. Eng. Struct Dyn.* 45(4), 507–524.
- [18] Furtado, A. et al., Rodrigues, H., Arède, A., Varum, H., 2016. Experimental evaluation of out-of-plane capacity of masonry infill walls. *Eng Struct.* 111, 48–63.
- [19] Gautam, D., & Chaulagain, H., 2016. Structural performance and associated lessons to be learned from world earthquake in Nepal after 25 April 2015 (MW 7.8) Gorkha earthquake. *Engineering Failure Analysis*. 68, 222–243.
- [20] Hak, S. et al., 2014. Out-of-plane experimental response of strong masonry infills, in: 2nd European conference on earthquake engineering and seismology.
- [21] Hashemi, S.A., & Mosalam, K.M., 2007. Seismic evaluation of reinforced concrete buildings including effects of infill masonry walls, PEER 2007/100. University of California, Berkeley, CA.
- [22] IS 1983, 2002. Indian standard criteria for earthquake resistant design of structures-part i: general provisions

- and buildings. Bureau of Indian Standards. New Delhi, India.
- [23] Koutas, L.N., & Bournas, D.A., 2019. Out-of-Plane Strengthening of Masonry-Infilled RC Frames with Textile-Reinforced Mortar Jackets. *J. Compos. Constr.* 23, 04018079.
- [24] Moreno-Herrera, J. et al., 2016. Out-of-plane design procedure for confined masonry walls. *J. Struct. Eng.* 142, 04015126.
- [25] Murakami, H. et al., 2015. Seismic Intensity Questionnaire Survey for the 2015 Gorkha, Nepal Earthquake - Preliminary Results and Damage Observations. JAEI Conference, Tokyo.
- [26] Nasiri, E., & Liu, Y., 2019. The out-of-plane behaviour of concrete masonry infills bounded by reinforced concrete frames. *Eng. Struct.* 184, 406–420.
- [27] NBC 105, 1994a. Seismic Design of Buildings in Nepal. National Building Code. Government of Nepal, Kathmandu.
- [28] NBC 201, 1994b. Mandatory rules of thumb: reinforced concrete buildings with masonry infill. National Building Code. Government of Nepal, Kathmandu.
- [29] NBC 205, 1994c. Mandatory rules of thumb: reinforced concrete buildings without masonry infill. National Building Code. Government of Nepal, Ministry of Physical Planning and Works, Kathmandu.
- [30] NPC, 2015. Nepal Earthquake 2015: Post Disaster Needs Assessment. National Planning Commission, Government of Nepal, Kathmandu.
- [31] Petrus, C. et al., 2015. Reinforced concrete frames with masonry infills. Out of plane experimental investigation. *Acta Technica Napocensis*.
- [32] Pradhan, B. et al., 2020. A macro-element modelling technique to account for IP and OOP interactions in URM infilled RC or steel building, in: *Proceedings of the 17th International Brick and Block Masonry Conference. From Historical to Sustainable Masonry, Krakow*, pp. 891-899.
- [33] Preti, M. et al., 2015. Experimental testing of engineered masonry infill walls for post-earthquake structural damage control. *Bull. Earthq. Eng.* 13(7), 2029-2049.
- [34] Ricci, P. et al., 2011. 6th April 2009 L'Aquila earthquake, Italy: reinforced concrete building performance. *Bull. Earthq. Eng.* 9:285–305.
- [35] Ricci, P. et al., 2018. Experimental investigation of the influence of slenderness ratio and of the in-plane/out-of-plane interaction on the out-of-plane strength of URM infill walls. *Constr. Build Mater.* 191, 507-522.
- [36] Sharma, K. et al., 2018. Post Disaster Reconstruction after 2015 Gorkha Earthquake: Challenges and Influencing Factors. *J. Inst. Eng.* 14, 52–63.
- [37] Shing, P. B., & Mehrabi A. B., 2002. Behaviour and analysis of masonry-infilled frames. *Prog. Struct. Eng. Mater.* 4, 320-31.
- [38] Silva, L. et al., 2016. Experimental evaluation of a constructive system for earthquake resisting masonry infill walls, in: *Brick and Block Masonry Conference. (IB2MAC)*, Padua.
- [39] Vailati, M. et al., 2017. Earthquake-safe and energy-efficient infill panels for modern buildings, in: *International conference on earthquake engineering and structural dynamics. Springer, Cham*, pp. 233–261.
- [40] Varela-Rivera J. et al., 2012b. Confined masonry walls subjected to combined axial loads and out-of-plane uniform pressures. *Can. J. Civ. Eng.* 39, 439–447.
- [41] Varela-Rivera, J. et al., 2012a. Out-of-Plane strength of confined masonry walls. *J. Struct. Eng.* 138, 1331–1341.
- [42] Varum, H. et al., 2017. Seismic performance of the infill masonry walls and ambient vibration tests after the Gorkha 2015, Nepal earthquake. *Bull. Earthq. Eng.* 15 (3), 1185–1212.
- [43] Verlato, N. et al., 2016. Innovative systems for masonry infill walls based on the use of deformable joints: combined in-plane/out-of-plane tests, in: *Proceedings of the 16th International Brick and Block Masonry Conference 2016*.



## Types and Sizes of Structures in Rural Housing Reconstruction in the Socio-Economic Context of Nepal

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*Keywords: Structure type, plinth area, housing reconstruction, caste/ethnicity, family size.*

### Abstract

The 2015 Mw 7.8 Gorkha, Nepal earthquake damaged a large number of low strength masonry structures that created the need for large scale housing reconstruction. The owner-driven approach of housing reconstruction adopted by the Government of Nepal made homeowners responsible for the selection of structure type, size, and construction of the house. This paper explores the types and sizes of houses built in rural areas under the housing reconstruction program and its relation to caste/ethnicity and family size using descriptive and inferential analysis. The results show that 45.2 percent and 34 percent of households built stone masonry with mud mortar and brick masonry with cement mortar houses, respectively, and 96 percent of households constructed houses with one-story and one-story with an attic. The mean plinth area of reconstructed houses was 361.1 sq. ft. The paper concludes that the houses were built using traditional materials and the housing reconstruction had also introduced new types of structures in rural areas. Structure type and plinth area were significantly affected by caste/ethnicity but that had no effects on the number of stories. However, the number of stories was significantly affected by family size but that had no effects on the plinth area. The paper recommends that the government should continue with the technical standards and also continue to provide technical assistance even after housing reconstruction is completed.

### 1. Introduction

Mud-bonded brick or stone masonry houses are housing structures in rural areas with stone masonry preferred in the hilly regions (CBS, 2014b; DUDBC, 2011). The houses in rural hilly areas have rectangular plans and are situated on the sunny slope of hills with longer façade facing towards the south (Bodach et al., 2014). The stone masonry structures in rural Nepal

are generally 1-3 storied with shallow foundations (Varum et al., 2018). Most of the houses are built with traditional materials like mud mortar, stone. Even when they were constructed using modern materials like cement mortar, fired brick, and reinforced concrete the construction quality was poor causing the houses to perform poorly during the earthquake (Bothara et al., 2016). The 2015 Mw 7.8 Gorkha, Nepal earthquake severely affected the housing and human settlement

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sector damaging a large number of houses (NPC, 2015; NRA, 2016b). According to the National Reconstruction Authority (NRA), of 1,047,261 damaged houses surveyed, 78.4 percent were of low strength masonry, 7.87 percent cement-mortared masonry and only 3.57 percent were reinforced concrete houses (NRA, n.d.). Most of the damaged houses were low strength masonry due to their poor seismic performance (Goda et al., 2015). The widespread damage created the need to rebuild houses in accordance with seismic standards to provide safe shelter to affected people.

The Government of Nepal adopted an owner-driven reconstruction approach for housing reconstruction that made homeowners responsible for selecting size and type of structure of the house to be built (NPC, 2015). A disaster can be an opportunity to build better than the past condition (Ophiyandri et al., 2010) and housing reconstruction efforts can help to minimize the possible future disaster effects by making the community more sustainable and resilient (Labadie, 2008). To ensure that houses were built back better the Government of Nepal supported homeowners through grant assistance in multiple tranches that were receivable only after technical verification of the houses (NRA, 2016a).

The NRA provided the technical standards, design catalogs, inspection guidelines, and other manuals, and technical assistance through engineers to monitor construction. It deployed technical teams in earthquake-affected districts to facilitate the distribution of housing grants and provide technical assistance, and verify built structures from April 2016 (Over 1,300 engineers deployed, 2016). The promotion of multiple technologies was found to be successful compared to a single one during the reconstruction process (Vahanvati & Mulligan, 2017). NRA introduced prototype designs through the design catalog based on the Nepal National Building Code (NBC). These catalogs provided flexible designs that could be adopted in all earthquake affected areas (DUDBC, 2015). The prototypes introduced in Volume I of the catalog were of stone masonry with mud mortar (SMM), brick masonry with mud mortar (BMM), stone masonry with cement mortar (SMC), and brick masonry with cement mortar (BMC) structures

(DUDBC, 2015). Volume II of the design catalog recognized 12 other technologies that were developed to pave way for use of alternate materials and technologies in housing reconstruction (DUDBC, 2017). NRA discouraged prefabricated buildings as a policy because it sought to promote use of local material and skills to restore traditional architecture (NRA, 2016b). It also introduced technical standards as Minimum Requirements (MR) to check and ensure compliance to the standard for seismic resistant building design based on NBC. The MR specified the shape and size of the house for different structure types. Technical standards made it difficult for SMM and BMM houses to be more than one story with attic but households added a floor using light materials to fulfill functional requirements. This then caused the NRA to develop the hybrid structure manual and other guidelines to provide construction guidelines for the emerging new construction typologies (NRA, 2017).

Types of housing structures in Nepal vary by ecology and geography of the site as well as by caste/ethnicity, and economic conditions (CBS, 2014c). Brahmin, Chhetri, Newar, and Thakali are socio-economically better-off than Dalit and Janajati (CBS, 2014a) with better literacy rate, financial capacity, and exposure to mass media (Bennett et al., 2008). High status and high-income occupations like management, and professional is common among the Brahmin-Chhetri whereas Dalit and Janajati are mostly engaged in elementary occupations (CBS, 2014b) and this also influenced their access to benefits from the housing reconstruction program (NPC, 2015). The size of the house depends upon socio-economic hierarchy (Wilk, 1983) and the size of the family living there (Naroll, 1962). Generally, extended families live in larger houses compared to nuclear families (Healan, 1977) but Wilk (1983) found that there was no significant difference between the size of houses of extended family and the nuclear family.

There are various studies on the challenges of housing reconstruction in developing countries (Kotani et al., 2020). Similarly, characteristics and seismic performance of different structure types and construction materials of damaged houses in Nepal have been



studied broadly (Bothara et al., 2016; Sharma et al., 2016; Varum et al., 2018). However, there are fewer studies about the typologies of structures built after an earthquake and therefore there is the need to document the types and sizes of structures built during Nepal's reconstruction to obtain an understanding of the structure typologies. During reconstruction there were also concerns of access as socio-economically disadvantaged groups like Dalit and Janajati (CBS, 2014a) were likely to face discrimination as there would be competition of resources (NPC, 2015). This study helps to understand the extent of social inclusion during the reconstruction process, which was a strategic recovery objective in the Post Disaster Recovery Framework (NRA, 2016b). The major objective of this paper is to explore the types and sizes of houses built in rural areas under the housing reconstruction program. The secondary aim is to explore the types of structures built with respect to caste/ethnicity and the sizes of structures built with respect to structure type, family size, and, caste/ethnicity.

## 2. Materials and methods

Types and sizes of houses constructed were studied in terms of family size and caste/ethnicity based on rural socio-economic context. The type of houses constructed was studied in relation to the type of structure built and building materials used. The size of the house was studied in terms of plinth area and the number of stories constructed. The total carpet area was not studied as most houses (over 96%) were less than two stories. The study did not assess the type and size of the house in terms of household income and construction cost, nor did it attempt to compare the size of structures built before and after the earthquake. The study did not explore why people selected a certain type and size of house.

### 2.1 Study area

The study was done in Gorkha and Sindhupalchowk, two districts most -affected by the earthquake (NPC,

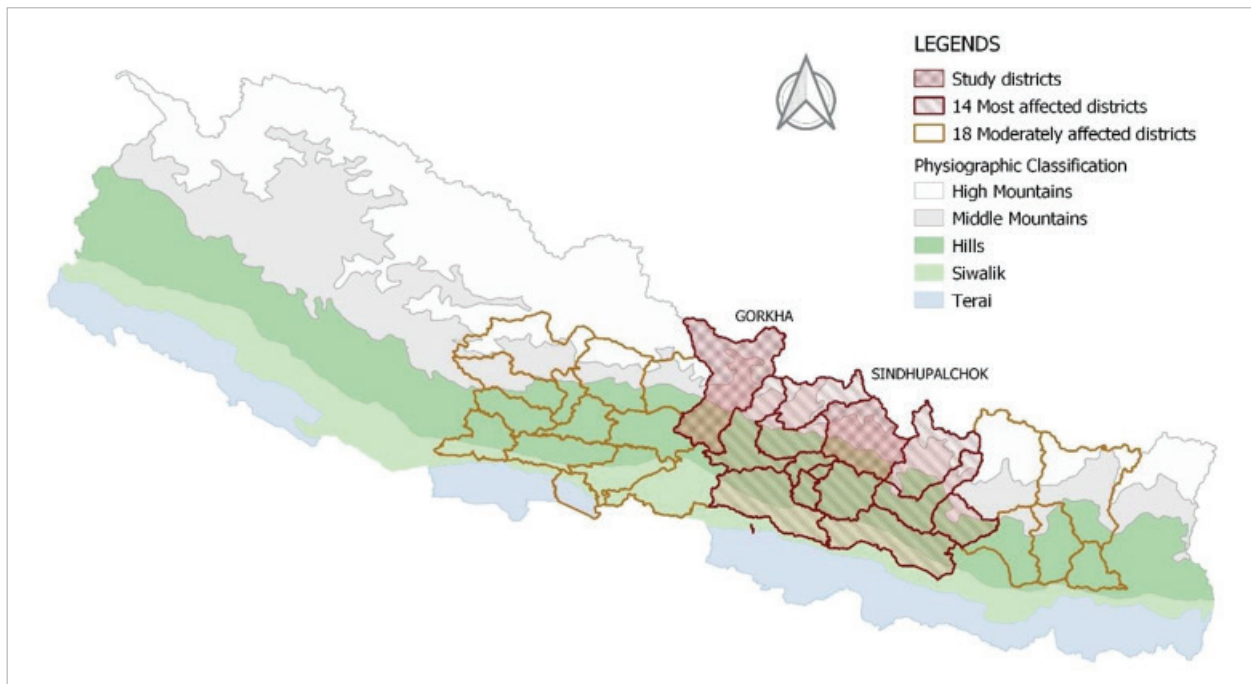


Figure1. Physiographic map of the study area and other affected districts (LRMP Nepal, 1986; Mainali & Pricope, 2017; NPC, 2015; Survey Department, 2020)

2015). Both districts fall in the same physiographic regions (Figure 1) - hill, middle mountain and high mountain (LRMP Nepal, 1986; Mainali & Pricope, 2017), and all beneficiary households included in this study were located in the hill and middle mountain regions. Due to the similarity in physiographic location, similar traditional building materials like stones, soil and timber were available in the study areas (Bodach et al., 2014), which may be reflected in structure type. Major areas of the 14 most-affected districts as well as 18 moderately affected districts fall in the hill and middle mountain region (Figure 1). Similarly, the data from the damage grade survey (NRA, n.d.) shows that 76.22 percent affected houses were located in the hilly region, 12.81 percent in the middle mountain region, and less than 11 percent in other three physiographic regions – high mountain, siwalik and the hills. The introduced design prototypes and technical standards were the same for all affected districts. Although the study did not include structures built in high mountains, siwalik and the Tarai regions, it is assumed that its findings can represent houses constructed in rural areas of all affected districts under the housing reconstruction program.

## 2.2 Data collection

The Emergency Housing Reconstruction Project (EHRP) database was the main source of data for this study. The database was maintained, updated, and monitored biweekly by the trained masons, engineers, and social mobilizers of the EHRP project. The database included information related to demography, location, construction status, and house outline of each household. In March 2020, the database included 95,117 beneficiaries from 109 wards (91 in Sindhupalchowk and 18 in Gorkha). The database was limited to 12 rural/urban municipalities of Sindhupalchowk and 18 wards across five rural/urban municipalities of Gorkha. The database was built using information obtained from the heads of household who were interviewed. The data on the size and types of houses were collected by trained masons and engineers during the interview.

The independent variables used were caste/ethnicity

and family size while the dependent variables were structure types, number of stories, and plinth area. The study used nine categories of structure types, which consisted of eight commonly built types – SMM, BMM, SMC, BMC, reinforced cement concrete (RCC), hybrid, light frame steel structure, and light frame timber structure – from the types that were recognized by the NRA. All other structures except the above eight types were categorized as “Others” which included structures like hollow block, compressed stabilized earth block (CSEB), confined masonry, etc. (DUDBC, 2015, 2017; NRA, 2016c, 2017, 2018). The study has used data on the plinth area and the number of stories to estimate house size. There were different technical standards to build a one-story house compared to one story house with attic (DUDBC, 2015) to account for which the study made a distinction between one-story and one-story with attic houses and also between two-story and two-story with attic houses.

The study has categorized caste/ethnicity based on classification by the Central Bureau of Statistics (CBS, 2014a) into five groups namely Brahmin-Chhetri, Dalit, Janajati, Newar-Thakali, and Others. We have included Brahmin-Chhetri and Newar-Thakali as socio-economically advanced groups. Others category includes all other caste/ethnicity groups, which did not belong to the above-mentioned categories and respondents who did not want to mention their caste/ethnicity. Similarly, family size has been classified in five categories – nuclear family with up to two members, small family with 3-4 members, extended small family with 5-6 members, large family with 7-8 members, and extended large family having more than 8 members (CBS & UNDP, 2016). The family size does not include family members not living in the house.

## 2.3 Data analysis

The research adopted a descriptive and inferential analysis. The initial cleanup of the database included looking only at those households that had started reconstruction of their houses and removing the data where information was missing. Analysis of categorical

variables with categorical variables was conducted using Pearson's Chi-square test of independence (McHugh, 2013), which was followed by a post hoc analysis using an adjusted  $\alpha$  value as described by Bonferroni (Beasley & Schumacker, 1995) for significant results. In the same way, a Games Howell post hoc analysis was used to compare the multiple levels of categorical variables and numeric variables for Analysis of Variance (ANOVA) tests, which revealed significant results. The categorical independent variables, with unequal sample sizes, were analyzed against the dependent numerical variables. Hence, we could not justify the differences observed between the categories of variables only through descriptive statistics. So, we used ANOVA and its post hoc test in identifying the significant results as a part of the inferential analysis. The first step was to refer to Levene's F test for homogeneity of variance. A significant result ( $p < 0.05$ ) for Levene's F test meant that the variance was not homogeneous – they were not equal. In such cases, we referred to a more robust Welch's F test. However, for categories that did not produce a significant result ( $p > 0.05$ ) for Levene's F test, that is the variances are more or less equal, we referred to the standard ANOVA table. The second step was to look at significant results for the ANOVA test or the more robust Welch's F. A significant result ( $p < 0.05$ ) meant that there was a significant difference between the variances of categories. However, it does not reveal the category that varied more. For this, Games Howell's Post Hoc test was used, when the variances were not equal, to elaborate the category that varied significantly.

### 3. Results and discussion

#### 3.1 Types of structure

Most of the households ( $N=89,784$ ) built SMM houses followed by BMC with 45.2 percent and 34 percent households adopting these structures, respectively (Figure 2). RCC structure was built by 13.9 percent households and the BMM structure was the least preferred type.

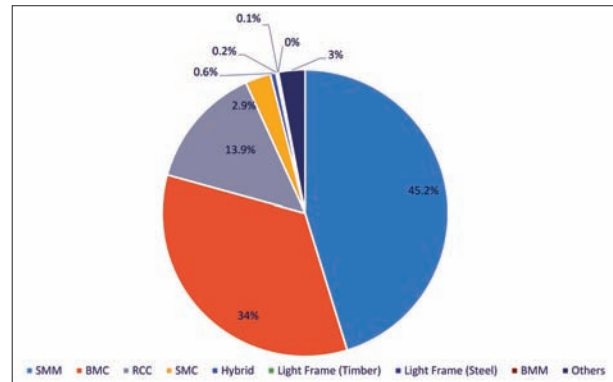


Figure 2. Types of structure

SMM was the most preferred structure used during reconstruction as both stone and mud were locally available. The damage grade survey data of Gorkha and Sindhupalchowk showed that SMM was the most common structure type before earthquake, 78.26 percent of the total houses (NRA, n.d.), which is higher than the number of SMM houses constructed after the earthquake. Some households had shifted from SMM to other structures after the earthquake. The number of BMC structures increased from 3.74 percent before the earthquake (NRA, n.d.) to 34 percent of the total structures after housing reconstruction. Beside the SMM and BMC types, people also built new types of structures – hybrid, light frame steel, hollow blocks, CSEB blocks, and confined masonry structures – after they were introduced by the NRA (DUDBC, 2017; NRA, 2017). RCC structures, built by only 2.56 percent households before the earthquake (NRA, n.d.), became one of the most popular structure type after the earthquake despite the higher cost, need for transport of construction material and being a relatively new technology in rural areas. This might be due to the perception of people about safety of RCC structures as the damage grade survey data (NRA, n.d.) showed that only a few RCC structures had been damaged compared to other structure types. Mud mortar is generally used in structures in areas where transportation of cement and sand is difficult. BMM was the least preferred structure type because households wanted to use cement mortar where the bricks could be transported easily.

### 3.2 Structure type and caste/ethnicity

A Pearson's chi-square test of independence showed that the independent variable caste/ethnicity caused a significant change,  $\chi^2 (32, n = 89784) = 2329.75, p < .001$ , on the dependent variable's structural typology with a small (Cramer's  $V = .08$ ) effect size. The condition for the expected count of less than 5 was violated for only 4 cells (8.9%), hence the results of Pearson's chi-square test were referred. A post hoc analysis using a Bonferroni adjusted alpha level of .0011 (.05/45) revealed that the 'Others' (44.8%) group built a significantly higher number of BMC structures compared to Brahmin-Chhetri (38.0%), Dalit (36.7%), and Janajati (29.6%) groups (Table 1). However, the choice of BMC structure was not dependent on the caste group Newar-Thakali. In the case of RCC structures, Newar-Thakali (23.6%) had a significantly higher number, and Dalit (7.5%) had the significantly lowest number compared to other castes/ethnicities. However, in the case of SMM structures, Janajati (49.7%) and

Dalit (47.8%) had the two highest proportions while Newar-Thakali (34.6%) and 'Others' (33.4%) group had the lowest proportions.

Caste/ethnicity had significant influence in the determination of the type of structure to be built. SMM structures were the most preferred structure types for all caste/ethnic groups except for "Others". A higher preference of SMM was found among Janajati and Dalit compared to Brahmin-Chhetri and Newar-Thakali. Highest number of RCC structures were constructed by Newar-Thakali and the lowest number by the Dalit. The relationship of caste/ethnic groups to the resources around them is different for different caste/ethnic groups (Massey et al., 2010). Social stratification is reflected in the structure type where a higher proportion of structure types with higher cost and made up of modern material were built by the socio-economically better off Newar-Thakali group. Similarly, a larger proportion of structure types with lower cost and traditional materials were built by groups with comparatively lower socio-economic situation. This

Table 1: Structure type and caste/ethnicity

Structure* Caste/Ethnicity	Brahmin-Chhetri N, R%	Dalit N, R%	Janajati N, R%	Newar-Thakali N, R%	Others N, R%	Total N, R%
BMC	10448, 37.95%*	2842, 36.67%*	12287, 29.56%*	3268, 34.23%	1525, 44.82%*	30370, 33.82%
BMM	1, 0.00%	3, 0.03%	13, 0.03%	2, 0.02%	1, 0.02%	20, 0.02%
Hybrid	280, 1.01%*	24, 0.31%	157, 0.37%*	42, 0.44%	5, 0.14%*	508, 0.56%
Light Frame (Steel)	29, 0.1%	6, 0.07%	40, 0.09%	19, 0.2%	4, 0.11%	98, 0.1%
Light Frame (Timber)	48, 0.17%	27, 0.35%	115, 0.27%*	6, 0.06%*	1, 0.02%	197, 0.22%
Others	642, 2.33%*	314, 4.05%*	1354, 3.25%*	304, 3.18%	115, 3.38%	2729, 3.04%
RCC	3639, 13.22%*	582, 7.51%*	5645, 13.58%*	2253, 23.60%*	583, 17.13%*	12702, 14.14%
SMC	714, 2.59%*	247, 3.18%	1277, 3.07%	346, 3.62%*	32, 0.94%*	2616, 2.91%
SMM	11726, 42.59%*	3704, 47.8%*	20673, 49.74%*	3305, 34.62%*	1136, 33.39%*	40544, 45.15%
<b>Total</b>	<b>27527, 100%</b>	<b>7749, 100%</b>	<b>41561, 100%</b>	<b>9545, 100%</b>	<b>3402, 100%</b>	<b>89784, 100%</b>

\* $p < .001$ , At Bonferroni, adjusted  $\alpha = .0011$



could be explained by financial capacity, literacy, and exposure to mass media of Brahmin-Chhetri and Newar-Thakali that is higher compared to that of the Dalit and Janajati (Bennett et al., 2008).

### 3.3 Number of stories

One story and one story with attic houses were built by over 96 percent households (N=85,142) with 78.77 percent being one-story houses and 17.8 percent one story houses with attic (Figure 3). Fewer than one percent households built houses with more than two-stories.

The traditional houses in rural areas of Nepal had generally multiple stories (Bodach et al., 2014; Varum et al., 2018) but we observed that the number of people building houses with more than two stories was very low during the reconstruction. The maximum number of stories that could be built for all structure types had been specified by the technical standards (DUDBC, 2015). Accordingly, SMM houses could have one-story with attic under general conditions, and required consultation with expert if an additional story was required. Although BMC and SMC houses could be constructed up to two-stories with attic, many households built only one story as the technical standards for double-storied house had more stringent requirements compared to a single-story house (DUDBC, 2015; NRA, 2016c). The financial ability of household and use of

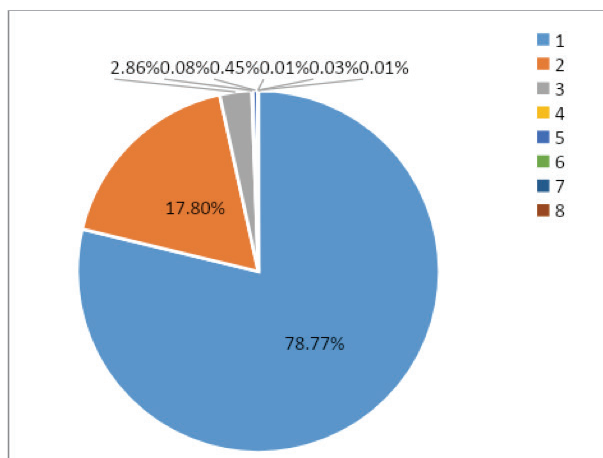


Figure 3. Number of story

transitional shelter or/and the old undemolished house for some function may have also influenced the decision on the number of stories. Plans for adding a story in the future (Lyons et al., 2010) might have been a factor while determining the number of stories built during the reconstruction.

### 3.4 Number of stories and structure

A Likelihood Ratio chi-square test for independence showed that the variable structural typology did not cause a significant change,  $\chi^2(56, n = 80352) = 50.64$ ,  $p = .68$ , on the variable, the number of stories. The Likelihood Ratio was adopted instead of Pearson's Chi-Square because 38 cells (52.8%) had the expected count less than 5.

Structure type did not cause a significant change in determining the number of stories built. Houses of all structure types were mostly one-storied and only less than four percent houses were two-stories or above. Technical standards made it difficult for mud mortar houses to have more than one story with attic but other popular structures like BMC, SMC could be raised to two stories with attic, while more than two floors of RCC structures could be constructed (DUDBC, 2015). Some households might have planned to add a story in the future (Lyons et al., 2010) but some of them had built an upper story with lightweight material in the single-story house during reconstruction (NRA, 2017).

### 3.5 Number of stories and caste/ethnicity

A Likelihood Ratio chi-square test for independence showed that the independent variable caste/ethnicity did not cause a significant change,  $\chi^2(28, n = 85114) = 27.16$ ,  $p = .51$ , on the dependent variable, the number of stories. The Likelihood Ratio was adopted instead of Pearson's Chi-Square because 14 cells (35%) had the expected count less than 5. The study found that caste/ethnicity did not cause significant change in determining the number of stories built, contrary to the argument made by Wilk (1983).

### 3.6 Number of stories and family size

The Likelihood Ratio chi-square test for independence showed that the independent variable family size caused a significant change,  $\chi^2(16, n = 7634) = 168.35$ ,  $p < .001$ , on the dependent variable, number of stories, with a small (Cramer's  $V = .07$ ) effect size. A post hoc analysis using a Bonferroni adjusted alpha level of .002 (.05/25) revealed that there was significant association for family size -- nuclear, small, and extended small with story/height of houses with one story and one story with attic. The analysis revealed that a significantly higher ( $p < .001$ ) percentage (87.3%) of nuclear families built only one story compared to small (80.0%) and extended small (73.8%) families, while a significantly higher ( $p < .05$ ) percentage (22.7%) of extended small families built one story with attic compared to small (16.4%) and nuclear (9.1%) families. The study found that the percentage of small and extended small families building two-story structures was also higher (3.3%) compared to nuclear families (3.2%) but the association was not significant ( $p > 0.05$ ) in all cases.

Family size caused a significant influence in the decision determining the number of stories built. More nuclear families built one-story houses. The decision to build one-story and one-story with attic, houses was significantly influenced by family size – nuclear, small, and extended. The result showed that a large

proportion of large and extended large families had also built one-storied houses. These families could be using the transitional shelter as a kitchen as had been observed in rural areas after the earthquake and could have been planning to add a story in the future (Lyons et al., 2010).

## 4. Plinth area

The mean plinth area of a house ( $N=88,366$ ) was 361.1 sq. ft. The result on the number of stories suggested that over 96 percent houses were under two-stories, and the mean plinth area tells us that most houses had two rooms (DUDBC, 2015). Horizontal extension to constructed houses (Lyons et al., 2010) can be seen in the future if the land is available. The Inter-Agency Common Feedback Project (CFP, 2018) also reported that the engineers had recommended building two-room structures.

### 4.1 Plinth area and structure type

A one-way between subjects' ANOVA was conducted to compare the structural typology of the house on the mean plinth area to determine if the choice of structure played any role in the square footage area of the house. The database used was considered to be normally distributed due to the central limit theorem for a very

Table 2 Number of stories and family size

Family size	Story					Total
	One	One with Attic	Two	Two with Attic	Three	
	N, R%	N, R%	N, R%	N, R%	N, R%	N, R%
Nuclear	2812, 87.30%*	294, 9.13%*	104, 3.23%	1, 0.03%	10, 0.31%	3221, 100%
Small	2071, 80.0%**	424, 16.37%**	86, 3.32%	1, 0.04%	8, 0.30%	2590, 100%
Extended Small	1107, 73.85%*	341, 22.75%*	49, 3.26%	0, 0.00%	2, 0.13%	1499, 100%
Large	222, 82.52%	37, 13.75%	9, 3.34%	0, 0.00%	1, 0.37%	269, 100%
Extended Large	47, 85.45%	7, 12.72%	1, 1.81%	0, 0.00%	0, 0.00%	55, 100%
<b>Total</b>	<b>6259, 81.98%</b>	<b>1103, 14.44%</b>	<b>249, 3.26%</b>	<b>2, 0.02%</b>	<b>21, 0.27%</b>	<b>7634, 100%</b>

\* $p < .001$ , \*\* $p < .002$ , At Bonferroni adjusted  $\alpha = 0.002$

large database (N=95711) (Ghasemi & Zahediasl, 2012). The Levene's F test revealed that the homogeneity of variance assumption was met ( $p = .594$ ). The comparison of the mean plinth area to structural typology failed to satisfy the homogeneity of variance assumption ( $p < 0.001$ ). As such, Welch's F test was used. The ANOVA test revealed a statistically significant effect of structural typology on mean plinth area, at  $p < .05$ , [Welch's  $F(8, 361.85) = 2137.25$ ,  $p < 0.001$ ]. The estimated omega squared ( $\omega^2 = .27$ ) indicated that approximately 27 percent of the total variation in mean plinth area was attributable to differences in structural typologies.

Post hoc comparisons, using the Games-Howell post hoc procedure, were done to determine which pairs of the structural typologies differed significantly. These results are given in Table 4 and indicate that BMC (M=331.89, SD=130.03) structure had significantly higher plinth area than SMM (M=320.26, SD=115.50) with an effect size of 0.12 and significantly lower plinth area than hybrid (M=398.11, SD=132.39), light frame steel (M=428.48, SD=179.02), light frame timber (M=380.92, SD=146.48), RCC (M=569.43, SD=202.51) and SMC (M=362.88, SD=144.50) with effect size of 0.71, 1.04, 0.53, 2.56 and 0.33, respectively. Similarly,

BMM (M=288.97, SD=131.21) structure had a significantly lower plinth area than hybrid, light frame steel, and RCC structures with effect size of 1.17, 1.49, and 3, respectively. Again, light frame steel had a significantly higher plinth area than "others" (M=326.63, SD=120.37), SMC, and SMM structures with effect size 0.8, 0.51, and 0.85, respectively, but significantly lower mean plinth area than RCC structures with effect size of 1.11. Light frame timber structures also reported significantly higher mean plinth area than "others" and SMM with effect size 0.52 and 0.58, respectively, but it was significantly lower than RCC with effect size of 1.81. "Others" category structures reported significantly lower mean plinth areas than RCC and SMC with effect size 2.83 and 0.42, respectively. While RCC structures reported a significantly higher mean plinth area than SMC and SMM with effect size of 1.44 and 1.73, respectively, RCC structures had a higher mean than all the structural typologies and SMM structures reported significantly lower mean plinth scores than SMC with an effect size of 0.41.

There was significant difference between the mean plinth area of different structure types. RCC houses had the highest mean plinth area while the mean plinth

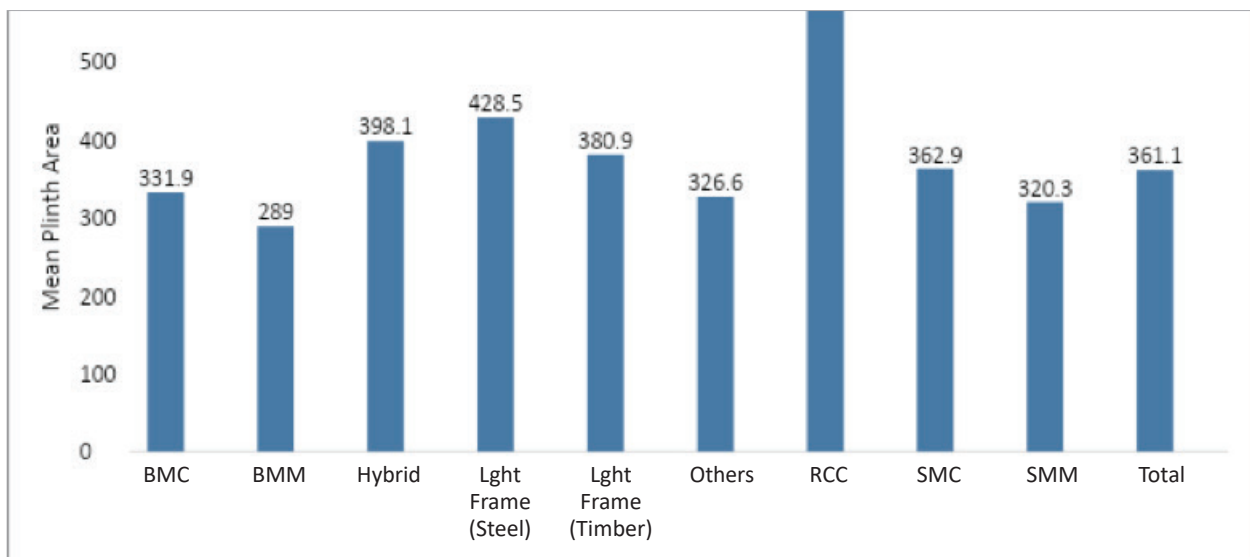


Figure 4. Mean plinth area corresponding to structure type

Table 3 Post hoc scores of plinth area by structural typology

Structure	Mean	Mean Differences (Effect Sizes are indicated in parentheses)								
		1	2	3	4	5	6	7	8	9
1. BMC	331.89									
2. BMM	288.97	42.91								
3. Hybrid	398.11	-66.23* (0.71)	-109.14** (1.17)							
4. Light Frame (Steel)	428.48	-96.59* (1.04)	-139.51** (1.49)	-30.37						
5. Light Frame (Timber)	380.92	-49.03* (0.53)	-91.95	17.19	47.56					
6. Others	326.63	5.26	-37.66	71.48* (0.76)	101.85* (0.80)	54.29* (0.52)				
7. RCC	569.43	-237.54* (2.56)	-280.46* (3.00)	-171.32* (1.81)	-140.95* (1.11)	-188.51* (1.81)	-242.8* (2.83)			
8. SMC	362.88	-31.00* (0.33)	-73.91	35.23* (0.37)	65.6** (0.51)	18.04	-36.25* (0.42)	206.55* (1.44)		
9. SMM	320.27	11.62* (0.12)	-31.29	77.85* (0.82)	108.21* (0.85)	60.66* (0.58)	6.36	249.17* (1.73)	42.62* (0.41)	

\* $p < .001$ , \*\* $p < .05$

area of BMM houses was the lowest. The plinth area of mud mortar structures was smaller compared to cement mortar structures. According to the technical standards, the maximum size of a single room that can be built is the same for all structure types but the number and size of rooms built for the different structures are different, which explained the difference

Table 4 Descriptive statistics of structural typology

Structural Typology	N	Mean	Std. Deviation
BMC	30054	331.888	130.0315
BMM	19	288.974	131.2112
Hybrid	505	398.114	132.3972
Light Frame (Steel)	98	428.48	179.0265
Light Frame (Timber)	197	380.921	146.4896
Others	2648	326.63	120.3743
RCC	12309	569.433	202.5127
SMC	2583	362.884	144.5081
SMM	39953	320.265	115.5034
<b>Total</b>	<b>88366</b>	<b>361.056</b>	<b>160.8282</b>

in the plinth area. Technical standards recommend one bay RCC structures only after consultation with experts (NRA, 2016c), which is difficult in rural areas. This caused most households who wanted to have RCC structures to build four-room houses.

#### 4.2 Plinth area and caste/ethnicity

A one-way between subjects' ANOVA was conducted to compare the differences in mean plinth area based on caste/ethnicity to determine if it played a major role in the decision on the square footage area of the house. The database used was considered to be normally distributed due to the central limit theorem for a very large database ( $N=88414$ ) (Ghasemi & Zahediasl, 2012). A Games Howell's post hoc test was performed between the variables as both, Welch's F test [ $F(4, 16332.43) = 222.58, p < 0.001$ ] and Levene's F test of homogeneity of variance ( $p < 0.001$ ) produced significant results. The Welch's F test revealed a statistically significant effect of caste/ethnicity on the plinth area, at  $p < .05$ . The estimated omega squared



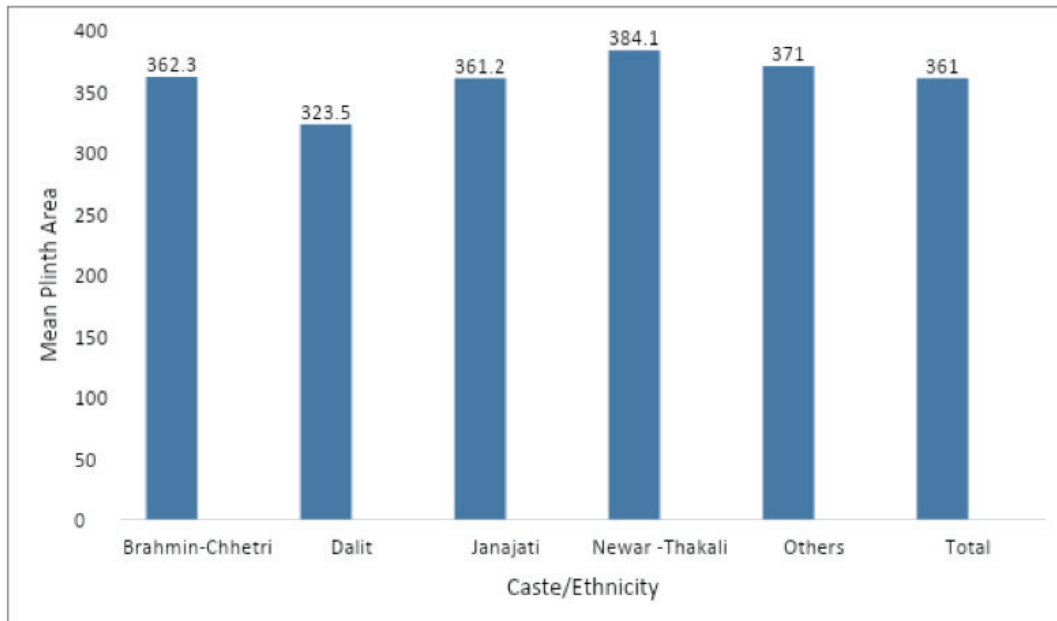


Figure 5. Mean plinth area corresponding to caste/ethnic groups

( $w^2 = .01$ ) indicated that approximately one percent of the total variation in mean plinth area was attributable to differences in structural typologies.

Post hoc comparisons, using the Games-Howell post hoc procedure, were done to determine which pairs of the caste/ethnicity differed significantly. These results are given in Table 6 and indicate that Newar-Thakali ( $M=384.14$ ,  $SD=167.36$ ) built houses with significantly bigger plinth area compared to

Brahmin-Chhetri ( $M=362.27$ ,  $SD=160.22$ ), Dalit ( $M=323.51$ ,  $SD=121.41$ ), Janajati ( $M=361.24$ ,  $SD=164.90$ ) and “Others” ( $M=371.03$ ,  $SD=160.38$ ) with an effect size of 0.13, 0.41, 0.13 and 0.08, respectively. Dalit households had built significantly smaller plinth areas compared to Brahmin-Chhetri, Janajati, Newar-Thakali, and “Others” with an effect size of 0.27, 0.26, 0.41, and 0.33, respectively. The Brahmin-Chhetri built a larger plinths compared to Janajati but the results

Table 5 Post hoc scores of plinth area by caste/ethnicity

	Caste/Ethnicity	Mean	Mean Differences (Effect Sizes are indicated in parentheses)				
			1	2	3	4	5
1.	Brahmin-Chhetri	362.271					
2.	Dalit	323.517	38.75* (0.27)				
3.	Janajati	361.241	1.03	-37.72* (0.26)			
4.	Newar-Thakali	384.146	-21.87* (0.13)	-60.62* (0.41)	22.90* (0.13)		
5.	Others	371.036	-8.76** (0.05)	-47.51* (0.33)	13.11* (0.06)	-13.11* (0.08)	

\* $p < .001$ , \*\* $p < .05$

were not significant while the “Others” group built a significantly larger plinth area compared to Brahmin-Chhetri, Dalit, and Janajati with an effect size of 0.05, 0.33, 0.06, respectively.

Table 6 Descriptive statistics of caste/ethnicity

Caste/ Ethnicity	N	Mean	Std. Deviation
Brahmin- Chhetri	27326	362.271	160.2206
Dalit	7593	323.517	121.4105
Janajati	41066	361.241	164.9058
Newar- Thakali	9075	384.146	167.3608
Others	3354	371.036	160.3871
<b>Total</b>	<b>88414</b>	<b>361.042</b>	<b>160.812</b>

Caste/ethnicity caused a significant effect on the mean plinth area. The mean plinth area of houses of the Newar-Thakali was the highest while it was lowest for the Dalit. The mean plinth area of all caste/ethnic groups except Dalit was higher than the overall mean plinth area. Newar-Thakali built the highest proportion of RCC houses, which had the highest plinth area,

while Dalit had built the lowest proportion of such houses. Social stratification was reflected in the house size, where bigger houses were built by socio-economically better off caste/ethnic groups; and smaller houses were built by groups with comparatively lower socio-economic situation. It also displayed the relationship between the socio-economic hierarchy and the size of the house (Wilk, 1983).

#### 4.3 Plinth area and family size

A one-way between subjects' ANOVA was conducted to compare family size and mean plinth area to determine if the choice of plinth area depended on the number of people living in the house. The database used was considered to be normally distributed due to the central limit theorem for a very large database (N=7303) (Ghasemi & Zahediasl, 2012). The Levene's F test revealed that the homogeneity of variance assumption was met ( $p=.45$ ). The one-way ANOVA test revealed that there was no significant difference in plinth area built at the  $p<.05$  level for any family size [ $F(4,88894.41)=0.882, p=0.474$ ].

Although the mean plinth area of houses of large and extended large families was slightly bigger than

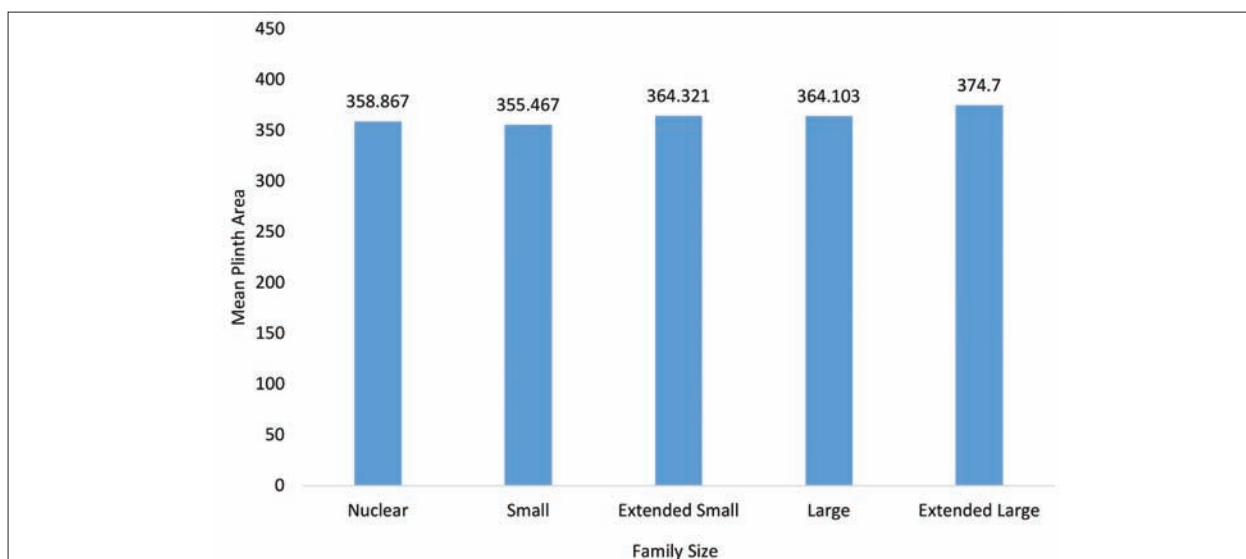


Figure 6. Mean plinth area corresponding to family size

nuclear and small families, the study found that the family size did not cause a significant effect on the plinth area of the structures built after the earthquake. The result is similar to the findings of Wilk (1983) who concluded that the size of the house was rather affected by socioeconomic hierarchy.

## 5. Conclusions and recommendations

The study on the type and size of structures built after the earthquake in rural areas revealed that SMM was the most-constructed structure type as the materials are available locally. The number of BMC and RCC structures has, however, increased. New structure types like hybrid, light frame (steel), hollow block, and CSEB block were also built in smaller numbers. A larger proportion of SMM structures was built by households lower on the socio-economic ladder and a larger proportion of RCC structures was constructed by Newar-Thakali, who were better off socio-economically. This suggested that caste/ethnicity was significant on the choice of structure type.

Most of the houses reconstructed were of one story. Houses with a two stories or above were sparse, showing the shift from pre-earthquake practice when traditional houses in rural hilly areas were generally multiple storied (Bodach et al., 2014; Varum et al., 2018). Technical standards as well as other factors like the availability of finance might have affected the number of stories built. It was found that both structure type and caste/ethnicity did not have a significant effect in determining the number of stories. However, family size had a significant influence in determining the number of stories as nuclear families had the highest proportion of a one-story houses.

The mean plinth area of the houses showed that most of the houses constructed after the earthquake had two rooms. A significant difference was found between the mean plinth area of the different structure types. The plinth area of the mud mortar structure was smaller compared to cement mortar and frame structure. It was observed that caste/ethnicity had a significant

relationship with the mean plinth area of the house. Larger houses were constructed by socio-economically well-off caste/ethnic groups and smaller houses were built by groups with comparatively lower socio-economic situation. It was also found that family size did not have a significant influence on the plinth area of the house.

In summary, houses built with traditional materials were continued after the earthquake, and new types of structures were also introduced. Almost all houses constructed in the housing reconstruction program were one-storied with two rooms. Structure type and plinth area were affected by social stratification but this had no influence on the number of stories of the house. However, the number of stories was affected by family size but this had no influence on the plinth area of the house.

The high number of one-storied houses are likely to extend in the future (Lyons et al., 2010). It is therefore recommended that the government should maintain the technical standards and continue to provide technical assistance to households even after completion of the housing reconstruction program. The social stratification should be considered for future policies of post-disaster reconstruction to provide special support to socio-economically disadvantaged caste/ethnic groups. The factors that caused the households to construct houses of the sizes and structural typologies discussed in this article is an area of further research. Another research area would be whether or not the house reconstructed is sufficient for people to continue their normal lifestyles.

## Acknowledgment

We would like to thank the technical assistance team at the EHRP project of the Central Level Project Implementation Unit (CLPIU Building) for data collection. We also thank the CLPIU Building and EHRP for allowing us to use the data. All the views presented in the article are of the authors and do not represent the views of CLPIU Building or EHRP.

## References

- [1] Beasley, T. M., & Schumacker, R. E., 1995. Multiple regression approach to analyzing contingency tables: Post hoc and planned comparison procedures. *The Journal of Experimental Education*. 64(1), 79-93. <https://doi.org/10.1080/00220973.1995.9943797>.
- [2] Bennett, L. et al., 2008. Caste, ethnic, and regional identity in Nepal: Further analysis of the 2006 Nepal Demographic and Health Survey. Population Division, Ministry of Health and Population, Government of Nepal. <https://dhsprogram.com/pubs/pdf/FA58/FA58.pdf>.
- [3] Bodach, S. et al., 2014. Climate responsive building design strategies of vernacular architecture in Nepal. *Energy and Buildings*. 81, 227-242. <https://doi.org/10.1016/j.enbuild.2014.06.022>.
- [4] Bothara, J. K. et al., 2016. The Challenges of Housing Reconstruction after the April 2015 Gorkha, Nepal Earthquake. *Technical Journal of Nepal Engineers' Association, Special Issue on Gorkha Earthquake 2015, XLIII-EC30*. 1, 121-134.
- [5] CBS (ed.), 2014a. Population monograph of Nepal (Vol. 1). Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics. <https://nepal.unfpa.org/sites/default/files/pub-pdf/PopulationMonograph2014Volume1.pdf>.
- [6] CBS (ed.), 2014b. Population monograph of Nepal (Vol. 2). Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics. <https://nepal.unfpa.org/sites/default/files/pub-pdf/Population%20Monograph%20V02.pdf>.
- [7] CBS (ed.), 2014c. Population monograph of Nepal (Vol. 3). Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics. <https://mohp.gov.np/downloads/Population%20Monograph%20V03.pdf>.
- [8] CBS, & UNDP, 2016. Annual Household Survey 2015/16 (Major Findings). Central Bureau of Statistics. <https://nada.cbs.gov.np/index.php/catalog/85>.
- [9] CFP, 2018. Community perception report; Reconstruction, Food Security, Livelihood and Protection. Inter-Agency Common Feedback Project, UN. <https://reliefweb.int/report/nepal/inter-agency-common-feedback-project-community-perception-report-reconstruction-food-1>.
- [10] DUDBC, 2011. Documentation of Indigenous Knowledge and Technologies for Safer Buildings. Department of Urban Development and Building Construction, Ministry of Urban Development, Government of Nepal.
- [11] DUDBC, 2015. Design Catalogue for Reconstruction of Earthquake Resistant Houses (Vol. 1). Department of Urban Development and Building Construction, Ministry of Urban Development. <https://www.dudbc.gov.np/download/cat/13>.
- [12] DUDBC, 2017. Design Catalogue for Reconstruction of Earthquake Resistant Houses (Vol. 2). Department of Urban Development and Building Construction, Ministry of Urban Development. <https://www.dudbc.gov.np/download/cat/13>.
- [13] Ghasemi, A., & Zahediasl, S., 2012. Normality Tests for Statistical Analysis: A Guide for Non-Statisticians. *International Journal of Endocrinology and Metabolism*. 10(2), 486-489. <https://doi.org/10.5812/ijem.3505>.
- [14] Goda, K. et al., 2015. The 2015 Gorkha Nepal Earthquake: Insights from Earthquake Damage Survey. *Frontiers in Built Environment*, 1. <https://doi.org/10.3389/fbuil.2015.00008>.
- [15] Healan, D. M., 1977. Architectural implications of daily life in ancient Tollán, Hidalgo, Mexico. *World Archaeology*. 9(2), 140-156. <https://doi.org/10.1080/00438243.1977.9979692>.
- [16] Kotani, H. et al., 2020. Transition of post-disaster housing of rural households: A case study of the 2015 Gorkha earthquake in Nepal. *International Journal of Disaster Risk Reduction*. 44, 101443. <https://doi.org/10.1016/j.ijdrr.2019.101443>.
- [17] Labadie, J. R., 2008. Auditing of post-disaster recovery and reconstruction activities. *Disaster Prevention and Management: An International Journal*. 17(5), 575-586. <https://doi.org/10.1108/09653560810918612>.
- [18] LRMP Nepal, 1986. Land resources mapping project. Survey Department, Government of Nepal and Kenting Earth Sciences. [https://issuu.com/manohardhami00/docs/land\\_resource\\_mapping\\_report\\_summar](https://issuu.com/manohardhami00/docs/land_resource_mapping_report_summar).
- [19] Lyons, M. et al. (eds.), 2010. Building back better:



- Delivering people-centred housing reconstruction at scale. Practical Action Pub. <http://lib.riskreductionafrica.org/bitstream/handle/123456789/264/building%20back%20better%20delivering%20people-centred%20housing%20reconstruction%20at%20scale.pdf?sequence=1>.
- [20] Mainali, J., & Pricope, N. G., 2017. High-resolution spatial assessment of population vulnerability to climate change in Nepal. *Applied Geography*. 82, 66-82. <https://doi.org/10.1016/j.apgeog.2017.03.008>.
- [21] Massey, D. S. et al., 2010. Environmental change and out-migration: Evidence from Nepal. *Population and Environment*. 32 (2-3), 109-136. <https://doi.org/10.1007/s11111-010-0119-8>.
- [22] McHugh, M. L., 2013. The Chi-square test of independence. *Biochemia Medica*. 143-149. <https://doi.org/10.11613/BM.2013.018>.
- [23] Naroll, R., 1962. Floor Area and Settlement Population. *American Antiquity*. 27(4), 587-589. JSTOR. <https://doi.org/10.2307/277689>.
- [24] NPC, 2015. Nepal Earthquake 2015: Post Disaster Needs Assessment Vol. A: Key Findings. National Planning Commission, Government of Nepal. [https://www.preventionweb.net/files/44973\\_lvw9argo0el2d-mpnt3gv20170223.pdf](https://www.preventionweb.net/files/44973_lvw9argo0el2d-mpnt3gv20170223.pdf).
- [25] NRA, 2016a. Grant Distribution Guideline. National Reconstruction Authority, Government of Nepal. <http://www.nra.gov.np/en/resources/details/ebUVxZtX4uarwnlIdilrr4la7SwaObKpVmXg2wpApCs>.
- [26] NRA, 2016b. Nepal Earthquake 2015: Post Disaster Recovery Framework 2016-2020. National Reconstruction Authority, Government of Nepal. [https://reliefweb.int/sites/reliefweb.int/files/resources/PDRF%20Report\\_FINAL10May.pdf](https://reliefweb.int/sites/reliefweb.int/files/resources/PDRF%20Report_FINAL10May.pdf).
- [27] NRA, 2016c. Private Housing Reconstruction, Technical Inspection Guideline. National Reconstruction Authority, Government of Nepal. [https://www.preventionweb.net/files/63760\\_fnasq59djh3wuk-o4ubh20180813.pdf](https://www.preventionweb.net/files/63760_fnasq59djh3wuk-o4ubh20180813.pdf).
- [28] NRA, 2017. Hybrid Structure Manual. National Reconstruction Authority, Government of Nepal. <http://nra.gov.np/uploads/docs/2dAI1Xt2rM171004013947.pdf>.
- [29] NRA, 2018. Light Timber/steel Frame Structure Manual. National Reconstruction Authority, Government of Nepal. <http://www.nra.gov.np/uploads/docs/3IMuU-H86we180422110212.pdf>.
- [30] NRA, E. H. R. P. (n.d.). Grade Wise Damage Assessment Report. Retrieved September 21, 2020. <https://ehrpmis.nra.gov.np/Report/ReportHierarchy/?p=ob+ACF2rxqg2xm9TaaqWoQ==>.
- [31] Ophiyandri, T. et al., 2010. Community based post disaster housing reconstruction: Indonesian perspective. <http://usir.salford.ac.uk/id/eprint/9761>.
- [32] Over 1,300 engineers deployed, 2016. Over 1,300 engineers deployed in 11 districts. The Kathmandu Post, 28 April. Retrieved June 7, 2020. <https://kathmandupost.com/national/2016/04/28/over-1300-engineers-deployed-in-11-districts>.
- [33] Sharma, K. et al., 2016. Field investigation on the performance of building structures during the April 25, 2015, Gorkha earthquake in Nepal. *Engineering Structures*. 121, 61-74. <https://doi.org/10.1016/j.engstruct.2016.04.043>.
- [34] Survey Department, 2020. Shapefile (GIS Data) for Political and Administrative Map of Nepal. Retrieved May 27, 2020. <http://dos.gov.np/download/news-events/shapefilegis-data-for-political-and-administrative-map-of-nepal>.
- [35] Vahanvati, M., & Mulligan, M., 2017. A new model for effective post-disaster housing reconstruction: Lessons from Gujarat and Bihar in India. *International Journal of Project Management*. 35(5), 802-817. <https://doi.org/10.1016/j.ijproman.2017.02.002>.
- [36] Varum, H. et al., 2018. Seismic Performance of Buildings in Nepal after the Gorkha Earthquake, in: *Impacts and Insights of Gorkha Earthquake in Nepal*. Elsevier, pp. 47-63. <https://doi.org/10.1016/B978-0-12-812808-4.00003-1>.
- [37] Wilk, R. R., 1983. Little house in the jungle: The causes of variation in house size among modern Kekchi Maya. *Journal of Anthropological Archaeology*. 2(2), 99-116. [https://doi.org/10.1016/0278-4165\(83\)90009-0](https://doi.org/10.1016/0278-4165(83)90009-0).



## An Assessment of Impact of Government Tranche Deadlines in Rural Housing Reconstruction of Nepal

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*Keywords: Housing reconstruction, tranche deadline, one-room, plinth area, compliance.*

### Abstract

Even after two years of the devastating earthquake, the monthly average second tranche of grant distribution in 11 most-affected districts was just 0.7 percent of the total identified beneficiaries. The National Reconstruction Authority adopted the deadline tranche disbursement in the housing reconstruction in July 2017. This paper assesses the impact of tranche deadlines in the speed of reconstruction, the number of one-room houses, size of house and quality of construction, through descriptive and inferential analysis using data of the Emergency Housing Reconstruction Project. It was found that the government tranche deadline accelerated the pace of reconstruction. The deadlines also caused an increase in the number of one-room houses and to a decrease in the plinth area, compared to the reconstruction trend before the deadlines were announced. We recommend the use of deadline in tranche disbursement for accelerating reconstruction, however, there must be adequate policy provisions to overcome the detrimental effects that deadlines can have on the size of houses reconstructed.

### 1. Introduction

The government of Nepal expected the reconstruction of houses of 827,255 beneficiaries (as of March 2020) (GMaLI, 2020) to take up to five years (NPC, 2015b). An owner-driven reconstruction (ODR) approach was adopted for housing reconstruction after the earthquake (Lam & Kuipers, 2019), making homeowners responsible for the construction of their house (NPC, 2015a). The ODR approach of reconstruction was found to be quicker than the donor-driven approach (Barakat, 2003; Duyne Barenstein, 2006) as communities had a stronger sense of ownership and incentive to rebuild

houses within shorter time frames (Andrew et al., 2013; Lam & Kuipers, 2019; Lyons, 2009). The Government of Nepal provided a grant of NRs. 300,000 (around US\$ 3,000) to eligible homeowners, disbursed through three tranches. A beneficiary was eligible to receive the first tranche (NRs. 50,000) after signing the participation agreement while the second (NRs. 150,000) and third tranches (NRs. 100,000) were disbursed only after technical verification when reconstruction had reached the plinth level and roof band level, respectively, to ensure Build Back Better (Lam & Kuipers, 2019; NRA, 2015). The technical verification was done by trained engineers based on technical standards developed by

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the NRA. The technical standards specified the measures to ensure the quality of the construction. The houses which could not meet the technical standards were declared non-compliant (NRA, 2016). The government's housing reconstruction grant had created a huge opportunity to promote safer housing. (NPC, 2015a)

Past experiences of other reconstruction programs with the ODR approach in developing and developed countries show timelines similar to that set by the Government of Nepal. After the 2005 earthquake Pakistan had formed the Earthquake Reconstruction and Rehabilitation Authority (ERRA) and adopted the policy of providing cash assistance of PKR 200,000 (around US\$ 1,300), which was disbursed in three tranches subject to fulfillment of physical conditions. Reconstruction of 93 percent of the completely damaged houses had been completed in 2010 (Shahnaz Arshad, 2013). Similarly, people affected by the Tsunami in 2004 in Sri Lanka were entitled to receive LKR 250,000 (around US\$ 1,400) cash grants payable in four installments for reconstructing a house (Lyons, 2009). The reconstruction of houses in Sri Lanka was estimated to be completed in 2009 but the timeline was extended till 2011 (ADB, 2012). Similarly, it took four years to meet Badan Rehabilitasi dan Rekonstruksi (BRR)'s target of rebuilding 125,000 permanent houses in Indonesia after the 2004 Tsunami (Lyons, 2009). However, in Japan it had taken five years to reconstruct 134,000 houses after the Kobe earthquake, and seven years to reconstruct 128,266 houses after the Great Kanto Earthquake (JICA, 2013). The timelines of reconstruction in past earthquakes informed the five-years reconstruction decision taken by Nepal after the 2015 Mw 7.8 Gorkha, Nepal earthquake.

National Reconstruction Authority (NRA) was established in December 2015 and it began distributing the first tranche of the reconstruction grant from March 2016 (NRA MIS, n.d.). It was expected that reconstruction would begin immediately after the first tranche was provided to the beneficiaries. However, the stakeholders doubted the efficiency of NRA officials because of the slow-speed of reconstruction (Daly et al., 2017).

Even after two years of the earthquake, the second tranche distribution rate to beneficiaries was only 0.7 percent. The beneficiaries had perceived that they could begin construction anytime, resulting in fewer number on houses being rebuilt compared to participation agreements that had been signed (NRA, 2017). The eight-month delay in the establishment of the NRA, followed by preparatory activities like validating beneficiaries and preparation of guidelines, were reasons that had slowed down the reconstruction at the outset (Limbu et al., 2019). The delay was attributed to the complicated administrative procedure and delayed government action (Kotani & Honda, 2019). NRA also introduced technical standards as Minimum Requirements (MR) to check and ensure compliance to the standard for seismic-resistant building design based on Nepal Building Code (NBC). MR also specified the measures needed to ensure the quality of the construction of houses and trained the engineers on how to check compliance. The houses that could not meet the quality standards and other standards were declared non-compliant (NRA, 2016). The reconstruction speed was also not as expected as the underlying implications of disaster for longer-term reconstruction were not fully understood by policy-makers and recovery practitioners (Chang et al., 2010). The NRA introduced the tranche deadlines in July 2017 to overcome the misperceptions of beneficiaries that they could begin construction anytime and to accelerate and complete reconstruction within five years as mandated (NRA, 2017). For this, NRA set the fiscal year 2017/18 as the year for collecting the second tranche (by mid-January), and the third tranche had to be received by mid-July 2018 (NRA, 2017). Almost 89.6 percent of the beneficiaries had received the first tranche by March 2017 (GMaLI, 2020) but the number of beneficiaries who had received the second and third tranches was very low (NRA, 2015). As of March 2020, 85.8 percent and 74.7 percent of the beneficiaries had received the second and third tranches, respectively (Figure 1).

Success in reconstruction is measured in terms of the number of houses constructed (Kennedy), as

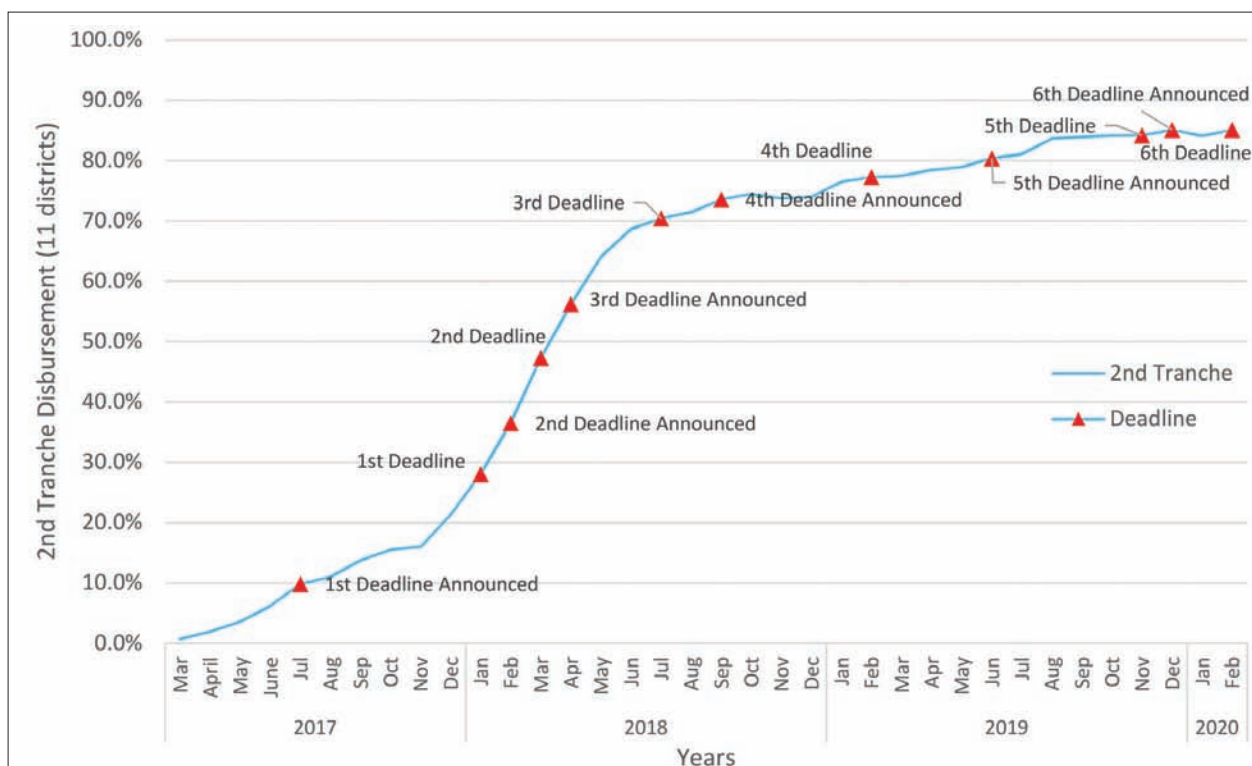


Figure 1. Trend of second tranche disbursement in 11 districts (GMAI, 2020)

quickly as possible. The reconstruction grant projects in Japan were established as a time-bound measure for the rigorous reconstruction time, intended to accelerate reconstruction of the disaster-affected areas (Hashimoto, 2016). UN-Habitat said that during the time of crisis after disasters, the highest achievements can be made in the shortest possible timelines (Lyons et al., 2010a). In Sri-Lanka, cut-off dates were set for the tranche disbursement, by which time the beneficiaries had to construct up to specific levels for receiving the next tranche, which was supportive in terms of speed of construction (Lyons, 2009).

However, past studies have also illustrated the impact of deadlines on reconstruction speed and quality. Deadlines given by donors create tension between speed and quality (Lyons et al., 2010a). The beneficiaries could not prioritize their needs of extended families, kitchen, open spaces, and private spaces because of the strict time limits (Siriwardena et al.,

2010). One of the reasons for beneficiaries to construct smaller houses not sufficient for their needs is the government tranche deadline (CFP, 2018). According to Steinberg (2007) compromises are made on essential constituents of reconstruction to complete it within the timeframe. Further, insufficient grant for construction compounded with unrealistic cut-off dates harmed the quality of construction (Lyons et al., 2010a).

Reconstruction of permanent housing is a continuous process that often needs decades of effort to return a community to normality (Sadiqi et al., 2012). Vahanvati and Mulligan (2017) have said the flexibility of time frame is required for reconstruction through the allocation of more time in the planning phase, time for gaining the trust of people, and also for the completion of the housing reconstruction phase. Shelter must not be considered as objects only, like tents or buildings, after disasters, but should be recognized as a series of activities to achieve the needs of people



(Kennedy et al., 2008), which needs a longer time (Steinberg, 2007). After a disaster where a number of houses have to be built as quickly as possible, it would present enormous challenges and would be highly demanding for agencies to build housing addressing individual beneficiary needs (Ahmed, 2011). It is important, therefore, to incorporate the contextual variations in program design in terms of time, cost, and other resource requirements, so that the desired outcomes are achieved (Lyons, 2009). Flexibility in the time frame was found to emphasize the owner-driven approach of reconstruction so that the people could build houses fulfilling all their needs and without any pressure. Policies after disasters in several countries have suggested that deadlines should be more flexible to ensure the effectiveness of projects (Lyons, 2009). Further, marginalized groups are also likely to be exposed to vulnerability because of unrealistic timelines (Solutions, 2019), and vulnerable beneficiaries have been unable to meet the deadlines of scaled-up ODR projects (Lyons et al., 2010a). The policy of NRA was to include everyone in the process of reconstruction (NPC, 2015). Therefore, in Nepal, the approach of not leaving anyone behind, caused the deadline to be extended six times (Figure 2) upon pressure from parliamentarians, local government representatives and

the beneficiaries in the earthquake-affected districts (NRA, 2019a).

After disasters, the approaches adopted for timely reconstruction have both advantages and disadvantages. It is therefore important to study the government policies and identify their impacts. Nepal decided to spend five years in reconstruction drawing from post-disaster reconstruction approaches elsewhere. However, there has not been a specific study on the impact of deadlines during reconstruction. This study attempts to understand the impact in the Nepali context that could inform future reconstruction policies. In the context of Nepal, it is also important to assess the impact of several extensions of the deadlines in terms of the effectiveness expected by the government when it took the decisions.

The purpose of this paper is therefore to assess the impact and effectiveness of these deadlines on different factors related to reconstruction. Its main objective was to assess the impact of government tranche deadlines towards increasing the speed of reconstruction. Another objective was to assess the impact of deadlines in the size and quality of the constructed house. This study was limited to the rural context of housing reconstruction and has analyzed data on reconstruction and tranche disbursements from March 2017 to February 2020.

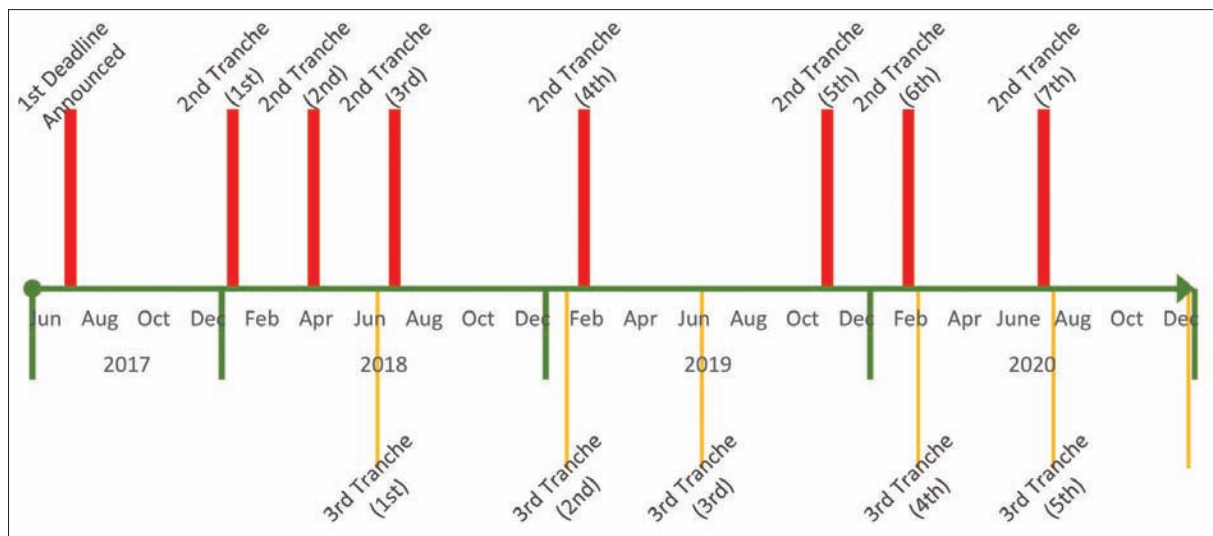


Figure 2. Government tranche deadline timeline (NRA, 2020)

### 1.1 Effect on the speed of reconstruction

Policies are often driven by the activities that support the speed in the progress and quicker completion of the projects (Barakat, 2003; Duyne Barenstein, 2006). The time-bound approach was successful to increase the speed in reconstruction (Hashimoto, 2016) and the success of the program is measured in terms of the number of houses constructed as quickly as possible (Kennedy et al., 2008). This will not only ensure the success of the policies but also bring the beneficiaries inside the house as quickly as possible.

H1. Deadlines will increase the speed of reconstruction.

### 1.2 Effect on quality of construction

Tranche disbursement was related to the construction of a house at a specific level, complying with all quality standards (Khadka, 2020; NRA, 2016). However, the pressure created by the deadlines forces the beneficiaries to compromise the quality to complete construction in time (Steinberg, 2007). The influences of deadlines generate confusion between speed and quality (Lyons et al., 2010a). As a result, financially weak beneficiaries could compromise input quality and construct non-compliant structures because they cannot compete in the market for better-skilled masons and good quality materials (Siriwardena et al., 2010).

H2. Deadlines will increase the number of non-compliant houses.

### 1.3 Effect on size of house and number of one room houses

The beneficiaries have chosen to build one-room houses, even though they are small (Lam & Kuipers, 2019). Beneficiaries tend to construct smaller houses during deadlines (CFP, 2018) as they cannot prioritize all their requirements because of the pressure created by deadlines (Siriwardena et al., 2010).

H3. Deadlines will decrease the size of the house.

H4. Deadlines will increase the number of the one-room houses.

## 2. Methodology

The study analyzed the impact of deadlines on the speed of reconstruction and other impacts like quality, size, and indebtedness through descriptive and inferential analysis. The study was done by analyzing the data of the start of reconstruction against different deadlines announced by the NRA, and when there was no deadline. In Nepal, the beneficiaries could receive the second tranche only after technical verification up to the plinth band and the third tranche only after technical verification up to the roof band. The number of rooms in the house and the plinth area is decided before receiving the second tranche. Hence for analysis, data of the start of reconstruction, number of one-room house, size of the house, and compliance to standards has been compared with the deadline of the second tranche

### 2.1 Data collection

The study area comprised of two of the most affected districts, Gorkha and Sindhupalchowk (NPC, 2015a). Emergency Housing Reconstruction Project (EHRP) database was the main source of data for this study. The database was maintained, updated and monitored biweekly through combined efforts of trained masons, engineers, and social mobilizers of the EHRP. The database included more than 100 types of information related to demography, location, construction status, and house outline of each beneficiary. As of March 2020, this database covered 95,117 beneficiaries. The database was, however, limited to 12 rural/municipalities of Sindhupalchowk and five rural/municipalities of Gorkha where the project worked. Household heads were interviewed to collect the data and information used for this research included the construction start dates, deadline intervals for second tranche, number of rooms, plinth areas, and compliance status. The independent variable was the deadline intervals, which was analyzed against the dependent variables – number of rooms, plinth area, and compliance status. Mobile masons at EHRP collected the data of one-room, plinth

area, and compliance status, which was verified by the engineers. The mobile masons, engineers, and social mobilizers were trained for data collection and compilation.

This paper has assumed that the effect of the deadline for Gorkha and Sindhupalchowk, and other rural districts would be similar as the deadline was same for all districts, and the technical assistance was also uniform for all areas. However, reconstruction was delayed in urban areas (Apurva et al., 2020). Similar to the experience in China (Chang et al., 2012), the reconstruction of the Kathmandu valley was also delayed because of complexities associated with urban areas (NRA, 2019b). Therefore, this study is limited to rural housing reconstruction. The study also assumed that the beneficiaries started the construction immediately after the earthquake and the data is compared accordingly. The start time of the construction of the house also might be affected by the affordability, geography, and engineer's availability, and choice of materials. Because of the limitation of the information in the EHRP database, this study did not consider the factors above, including the debt situation. The paper does

not also consider the deadline of second tranche after March 2020.

## 2.2 Data analysis

The research used a descriptive and inferential approach to analysis, which has been done in two parts. Firstly, to compare the speed of reconstruction, the data of house construction started immediately after the earthquake has been also taken into consideration. The rate of reconstruction was calculated for the period from April 2015 to February 2020, which was expected to facilitate analysis of the speed of reconstruction before and after the NRA was established, and after the first tranche was disbursed. The rate of reconstruction was calculated based on the number of house constructions started during that period and the construction that had not begun but needed to be done. The monthly rate was calculated by dividing the reconstruction rate during that period by the number of months. As the rate also needed to consider the beneficiaries who did not start construction until February 2020, the data of all 95,117 beneficiaries were compared

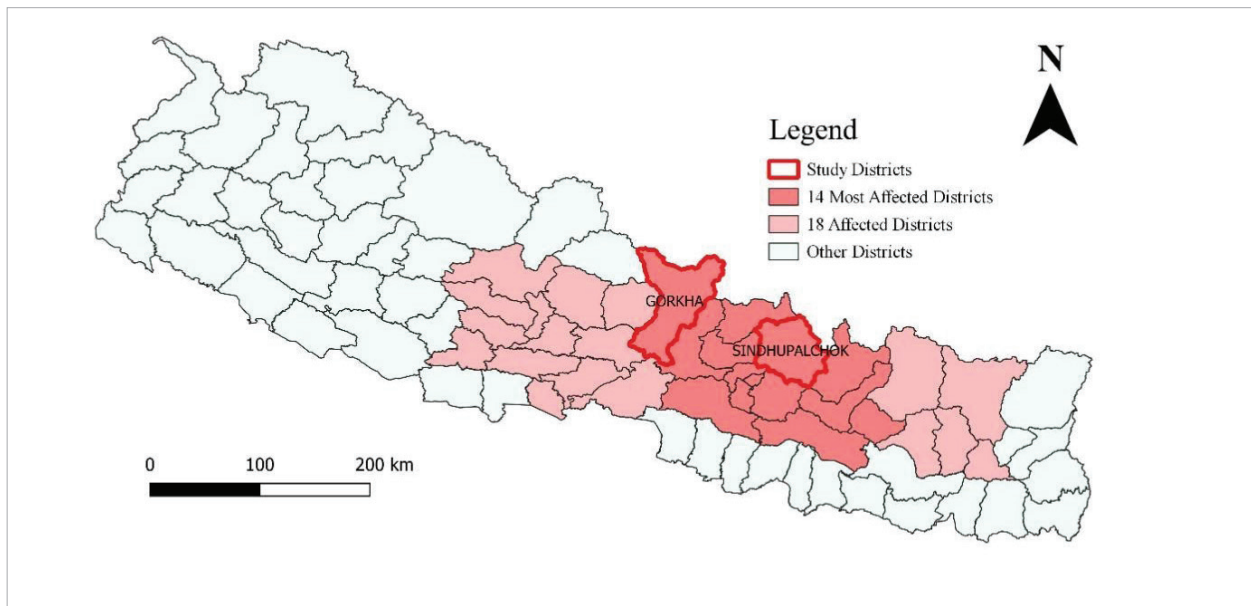


Figure 3. Study area and other earthquake affected districts (NPC, 2015a; Survey Department, n.d.)

to assess the rate of reconstruction. When the deadline was announced, the NRA expected all the construction to be completed within the deadline (NRA, 2017). The analysis of the monthly rate of construction had the same assumption.

The second part assesses the impact of the deadline in the number of one-room houses, size of the house, and quality of construction. The initial clean-up of the database included looking only at those beneficiaries, who had started house construction between March 2017 and February 2020, and removing the data with missing information. Pearson's Chi-square test

of independence was used for the analysis of categorical variables with categorical variables (McHugh, 2013), which was followed by a post hoc analysis using an adjusted  $\alpha$  value as described by Bonferroni (Beasley & Schumacker, 1995) for significant results. In the same way, the Analysis of Variance (ANOVA) test was used for comparing categorical and numeric data like deadline interval and plinth area. The categorical independent variables, with unequal sample sizes, were analyzed against the dependent numerical variables and therefore, we could not justify the differences observed in the means between the categories

Table 1: Deadline Intervals

SN	Deadline Intervals (Name)	From	To	Remarks
1	Before Deadline Announcement	April 2015	June 2017	To check speed
		March 2017 (Month of Data collection Start)	June 2017 (Before the month of 1st Deadline Announcement)	To check size, one room and compliance
2	1st Deadline Interval	July 2017 (Month of 1st Deadline Announcement)	January 2018 (Month of 1st Deadline)	For all results
3	2nd Deadline Interval	February 2018 (Month of 2nd Deadline Announcement)	March 2018 (Month of 2nd Deadline)	
4	3rd Deadline Interval	April 2018 (Month of 3rd Deadline Announcement)	July 2018 (Month of 3rd Deadline)	
5	No Deadline (A)	August 2018		
6	4th Deadline Interval	September 2018 (Month of 4th Deadline Announcement)	February 2019 (Month of 4th Deadline)	
7	No Deadline (B)	March 2019	May 2019	
8	5th Deadline Interval	June 2019 (Month of 5th Deadline Announcement)	November 2019 (Month of 5th Deadline)	
9	6th Deadline Interval	December 2019 (Month of 6th Deadline Announcement)	February 2020 (Month of 6th Deadline)	



of the variables only through descriptive statistics. So, we used ANOVA and its post hoc test in identifying significant results as a part of the inferential analysis. The first step was to refer to Levene's F test for homogeneity of variance. A significant result ( $p < 0.05$ ) for Levene's F test meant that the variance was not homogeneous or not equal. In such cases, we referred to a more robust Welch's F test. However, for categories that did not produce a significant result ( $p > 0.05$ ) for Levene's F test, that is the variances were more or less equal, we referred to the standard ANOVA table. The second step was to look at significant results for the ANOVA test or the more robust Welch's F test. A significant result ( $p < 0.05$ ) meant that there was a significant difference between the variances of categories. However, it did not reveal which category varied more. The Games Howell's post hoc test was used when the variances were not equal, to elaborate which category varied significantly. The Games Howell post hoc analysis was used to compare the multiple levels of categorical variables and numeric variables for ANOVA tests, which revealed significant results.

The timeline of three years was divided into nine intervals called deadline intervals. The size of the house was determined using the information of the plinth area constructed by the beneficiaries. The quality of the house was checked using information on compliance of the house to the building standard. To assess the effect of the deadline on these factors, all these data was analyzed against the different category deadline intervals.

### 3. Results and discussion

#### 3.1 Impact on the speed of construction

Table 2 shows that the highest monthly rate of the reconstruction took place at an interval after the second deadline, between February 2018 and March 2018. The second highest rate of monthly reconstruction took place in the seven months after the first deadline; this was followed by the monthly rates in the interval after the third and fourth deadlines. The lowest monthly rate of reconstruction took place in the interval after the

sixth deadline ( $< 1\%$ ). Reconstruction was low when there was no deadline. Similarly, the rates were also low in months before the deadline announcement, and the fifth deadline interval. The findings showed that reconstruction rates during the first, second, and third deadlines were significantly higher than the fifth, sixth, deadlines and also when there was no deadline, and before the deadline was announced. The reconstruction rate in the fifth and sixth deadline intervals was even lower than the rate in months when there was no deadline. This suggested that the extended fifth and sixth deadlines did not affect the speed of reconstruction. The findings confirmed that the speed of reconstruction was affected by the deadlines and proved the hypothesis that the deadlines increase the speed of reconstruction. However, this was not true for the extended deadlines.

The study showed that the beneficiaries had started reconstruction immediately after the earthquake using the means they had available. The delay in the establishment of NRA, preparation of technical guidelines, training the masons and engineers, and deploying them in the field also contributed to the slow takeoff of government-supported reconstruction (Daly et al., 2017; Limbu et al., 2019). This changed in July 2017, when the first deadline was announced and that speeded up the rate of reconstruction. The beneficiaries who had been waiting to begin rebuilding houses after the earthquake were informed that they could receive government support only if they constructed the houses within the government's tranche deadline (Diplomat, 2018). This explained the highest number of house construction that took place at this time. The result also showed that the beneficiaries were still preparing to start the construction in the first deadline interval, and they began rebuilding in the second deadline interval. The first and second deadlines had the biggest impact on reconstruction and a large number of beneficiaries had received the second tranches before the deadline. The short government tranche deadline, requirement of technical verification, and the complicated process of getting housing grants (Daly et al., 2017) created pressure on the beneficiaries to complete the housing

Table 2: Rate of reconstruction

SN	Deadline Interval	No of Months	Construction Started (Actual)	Construction Started (Target)	Reconstruction Rate	Monthly Reconstruction Rate
1	Before Deadline Announcement	26	20,073	95,117	0.211034831	0.008116724
2	1st Deadline Interval	7	41,923	75,044	0.558645595	0.079806514
3	2nd Deadline Interval	2	10,329	33,121	0.311856526	0.155928263
4	3rd Deadline Interval	4	6,130	22,792	0.268954019	0.067238505
5	No Deadline (A)	1	286	16,662	0.017164806	0.017164806
6	4th Deadline Interval	6	2,482	16,376	0.151563263	0.025260544
7	No Deadline (B)	3	444	13,894	0.031956240	0.010652080
8	5th Deadline Interval	6	946	13,450	0.070334572	0.011722429
9	6th Deadline Interval	3	285	12,504	0.022792706	0.007597569
	<b>Grand Total</b>	<b>58</b>	<b>82,898</b>			

reconstruction within the deadline. The extension of the deadline and the number of times this was done affected the peoples' trust on the government's deadlines, which was demonstrated by the low impact of later deadlines on reconstruction. Further, most of the beneficiaries had started construction within the deadline and those remaining were either vulnerable (Lyons et al., 2010a) or those who did not need houses immediately, or had another house.

### 3.2 Impact on compliance

There were several assumptions, including the likelihood of the deadlines pushing beneficiaries to opt for low-quality construction (Siriwardena et al., 2010). However, there was no significant difference between the deadline and compliance status with standards as revealed by Pearson's chi-square test of independence [ $\chi^2(8, n = 73015) = 135.44, p = .051$ ]. No cells violated the expected count for less than five conditions. The result showed that compliance

of the structure was independent of the deadline. The hypothesis regarding the impact of the deadline in increasing the number of non-compliant houses was, therefore, rejected. As tranche disbursement was dependent on technical verification, the beneficiaries could not compromise in construction quality.

### 3.3 Impact on size of house plinth area

A one-way between subjects' ANOVA was conducted to compare the effects of the deadline on the plinth area to determine if the deadlines played any role in determining the plinth area of the house. The database used was considered to be normally distributed due to the central limit theorem for a very large database ( $N=73015$ ) (Ghasemi & Zahediasl, 2012). Levene's F test revealed that the homogeneity of variance assumption was not met ( $p < .001$ ). As such, the more robust Welch's F test was used. The test revealed a statistically significant effect of the deadline on the plinth area, at  $p < .05$ , [Welch's  $F(8,2441.46) = 18.53, p < 0.001$ ]. The estimated

omega squared ( $w^2 = .002$ ) indicated that approximately 0.2 percent of the total variation in the plinth area was attributable to different deadline intervals.

Post hoc comparisons, using the Games-Howell post hoc procedure, were done to determine which pairs of the plinth areas differed significantly in which deadline interval. These results in Table 3 indicated that the plinth area built was significantly higher before the announcement of the deadline ( $M=375.66$ ,  $SD=164.82$ ) compared to the first ( $M=358.08$   $SD=155.75$ ), second ( $M=365.58$ ,  $SD=167.48$ ), and third ( $M=361.61$ ,  $SD=159.63$ ) deadline intervals and the effect of size was 0.11, 0.06 and 0.08, respectively. The plinth area in case of the fourth deadline interval ( $M=380.20$   $SD=178.44$ ) interval was significantly higher than the first, second, and third deadline intervals and the effect size was 0.13, 0.08, and 0.11, respectively. Similarly, the plinth area in case of the fifth deadline interval ( $M=386.71$   $SD=187.22$ ) was significantly higher than first, second, and third deadline intervals and the effect size was 0.16, 0.12 and 0.14, respectively.

The overall result reflected that the plinth area was affected by the deadlines. However, the different deadline intervals showed different effects and some deadlines did not have any effect. The result also showed that the size of the plinth area constructed before the deadline was higher than the size of the plinth area constructed after the first, second and third deadlines, when the plinth areas of the house had decreased. The beneficiaries had the impression that the cost of smaller houses would be lower and it would be easier to obtain government approval for the tranche (Lam & Kuipers, 2019). However, the plinth areas built in the fourth and fifth deadline intervals were higher compared to that before the deadline was announced. This suggested that the plinth area after the fourth and fifth deadlines were positively affected as indicated by the size of the plinth area. It was also found that there was no relation between the plinth area constructed before the deadline and the plinth area constructed during the months when there was no deadline. A similar result was seen for the sixth

Table 3: Post hoc scores of plinth area by the deadlinet

Structure	Mean	Mean Differences (Effect Sizes are indicated in parentheses)							
		1	2	3	4	5	6	7	8
1. Before Deadline Announcement	375.663								
2. 1st Deadline Interval	358.085	17.58* (0.11)							
3. 2nd Deadline Interval	365.581	10.08* (0.06)	-7.49* (0.05)						
4. 3rd Deadline Interval	361.618	14.04* (0.08)	-3.53	3.96					
5. No Deadline (A)	383.488	-7.82	-25.40	-17.90	-21.86				
6. 4th Deadline Interval	380.202	-4.53	-22.11* (0.13)	-14.62* (0.08)	-18.58* (0.11)	3.28			
7. No Deadline (B)	372.789	2.87	-14.70	-7.20	-11.17	10.69	7.41		
8. 5th Deadline Interval	386.710	-11.0	-28.62* (0.16)	-21.12* (0.12)	-25.09* (0.14)	-3.22	-6.50	-13.92	
9. 6th Deadline Interval	358.167	17.49	-0.08	7.41	3.45	25.32	22.03	14.62	28.54

\* $p < .05$

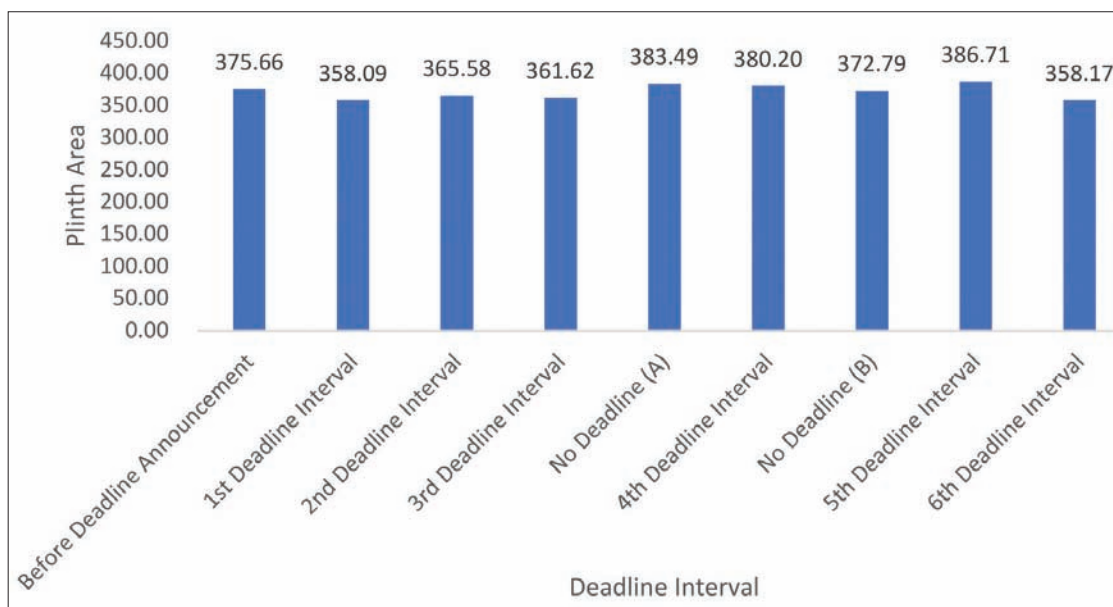


Figure 4. Mean plinth area in different deadline intervals

deadline interval. This suggested that the plinth area decreased after the deadline was announced, while exceptional result was observed for the fourth and fifth deadline intervals. Therefore, the hypothesis of the study was true only for the first, second, and third deadlines intervals.

The lowest average plinth area constructed during the deadline was equivalent to the size of a two-room house (DUDBC, 2015). This reflected that the beneficiaries constructed two-room houses irrespective of the deadlines. The increased cost of construction could be one of the reasons for the increased number of smaller, and one-room houses. The Inter-Agency Common Feedback Project (CFP, 2018) had said that the government's tranche deadline was one of the major factors influencing homeowners to build homes without due consideration of their needs. The NRA did not consider appointing additional human resources and monitoring the price of construction material (Limbu et al., 2019) when it announced the deadline. The extended deadlines did not have any impact on the construction of plinth areas, which indicated that there was no effect of the extended deadlines.

### 3.4 Impact on construction of one room house

A Pearson's chi-square test of independence was conducted showing that the independent variable deadline caused a significant change,  $\chi^2 (8, n = 73015) = 731.66$ ,  $p < .001$ , on the dependent variable one-room house with a small (Cramer's  $V = .1$ ) effect size. The condition for expected count less than 5 was not (0%), hence the results of the Pearson's chi-square test were referred. A post hoc analysis was done using a Bonferroni adjusted alpha level of .0028 (.05/18). The result revealed a significant result for all cases except for the first deadline interval ( $p = .162$ ) and no deadline (A) ( $p = .110$ ) and no deadline (B) ( $p = .028$ ). In case of 'Before deadline announcement' there was a significantly low ( $p < .001$ ) number of one-room houses than expected. But the number of one-room houses was significantly higher ( $p < .001$ ) for second, third, fourth, fifth, and sixth deadline intervals than the expected count. For the first deadline interval and no deadline (A) and (B), the number of one-room houses was higher than the expected count, even though no significant result was confirmed.



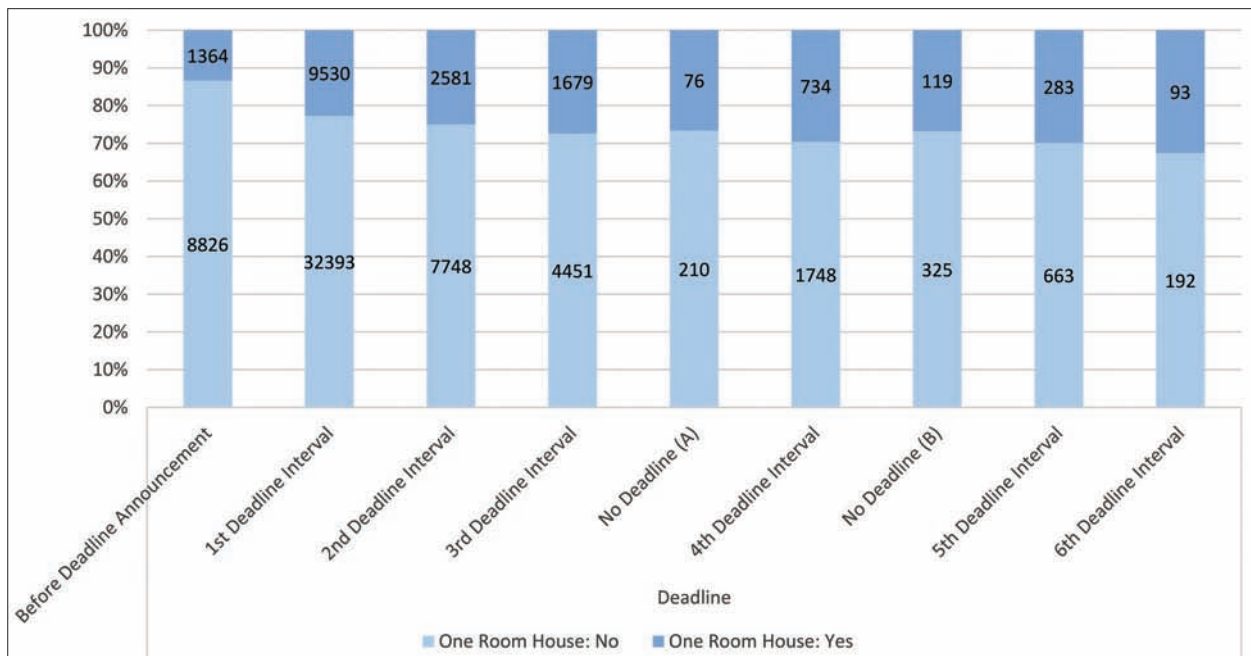


Figure 5. Proportion of one room houses built in different deadline intervals

The beneficiaries had begun constructing one-room houses, even before the deadline was announced but the number of houses was not high. The result showed that the beneficiaries who had already begun construction of one-room houses were not affected by the deadlines. However, there were significant effects of the second, third, fourth, fifth, and sixth deadline intervals. Accordingly, once the second deadline was announced, the pressure to complete the reconstruction on time pushed many beneficiaries to construct a one-room house (Limbu et al., 2019). As the impact of the deadline on speed of reconstruction was highest in the second deadline interval, it can be concluded that the second deadline was a major factor contributing to increasing the speed of reconstruction and preference for one-room house construction.

The result also showed that in case of the fifth and sixth deadline intervals, there was comparatively low effect on the speed of reconstruction but the effect was observed in the number of one-room houses. This might be the continuation of the trend that had been triggered by the second deadline to construct one room

houses, as they were also eligible for the grant tranche. As there were no restrictions for constructing one-room houses, the engineers also approved the houses easily (Lam & Kuipers, 2019), which also motivated other beneficiaries to have such houses. The beneficiaries constructed one room houses hurriedly to be able to receive the tranche, and there also was the possibility of both horizontal and vertical extension of the facilities (Lyons, 2009). Though many one-room houses were constructed to meet the tranche deadlines, it must be noted that the one-room house was also the preference of the elderly and disabled people, and one single woman (Khadka, 2020). Although the one-room houses were safer considering the compliance, there were possibilities that these houses would not meet the requirements of the house owners.

#### 4. Conclusions and recommendations

The study was done to assess the impact of the government tranche deadlines on the speed of reconstruction, quality of the house, size of the house, and

the number of one room houses. It has found that the impact varied in the different deadline intervals. After the announcement of the deadline, the beneficiaries were highly motivated to start the construction and receive the government grant tranches. The announcement of the second deadline with only two months to complete construction had the biggest impact on pushing the beneficiaries to begin construction. The study found that the first four deadlines had an impact on the speed of construction but fifth and the sixth did not as beneficiaries could have begun thinking that the deadline would be extended again. The tranche deadline had a good impact on the rate of construction as it enabled more beneficiaries to move into permanent houses in a short time. This study has concluded that the introduction of deadlines was effective in increasing the pace of reconstruction. However, the several extensions made to the deadline were not effective. This suggested that policy of having a deadline in housing reconstruction should be introduced only after considering the time necessary for all the beneficiaries to begin construction. The study has also suggested that different policies should be considered for people left behind rather than announcing more deadlines. It is likely that people who could not meet the deadline could be the more vulnerable members of communities as deadlines can only affect people who have the means to construct quickly. Finally, extending deadlines repeatedly was not an effective strategy because it could lead people to begin that it would be extended again.

The preference for one-room house construction was not affected by the announcement of the first deadline. But the pressure created by the second pushed beneficiaries to construct one-room houses and the trend continued till the sixth deadline. It was found that even though the fifth and sixth deadline had no impact on pace of construction, the construction of one-room houses had continued. The research has therefore suggested that policy should consider the

minimum number of rooms that have to be built for grant eligibility before construction begins.

The time-bound reconstruction with the deadline to receive grant tranches had a similar impact on the construction of comparatively smaller size houses, but the impact was seen only during the first three deadline intervals. After the fourth deadline, the extension of deadlines did not affect the construction of smaller size plinth areas. The study also revealed that the quality of construction was not affected by deadlines. This suggested that the beneficiaries would not compromise the quality of the construction if the tranche was linked to compliance of building norms.

The technical assistance in the areas of reconstruction must be continued as the beneficiaries would need support for expanding the house as per their needs (Lam & Kuipers, 2019). Besides, the deadline should be extended only for special types of beneficiaries yet to build houses for specific reasons as that would help make government policy credible and reliable.

As a conclusion from the understanding of the tranche deadline announcement and its impact, it can be suggested that grant tranche deadlines can be effective to increase the pace of house construction in post-disaster reconstruction where a large number of houses are required in a short period of time. However, such a policy would also need to also consider the influence of the government tranche deadline on the construction of one room or smaller size houses.

## Acknowledgments

We thank the technical assistance team of the EHRP of the Central Level Project Implementation Unit (CLPIU Building) for data collection. We also thank CLPIU Building and EHRP for allowing us to use the data and Mr. Tomoki Miyano, Team Leader of EHRP, for guiding and motivating us to write the paper.

All the views presented are of the authors and do not represent the views of CLPIU Building or EHRP.

## References

- [1] ADB, 2012. Sri Lanka: Tsunami-Affected Areas Rebuilding Project. <https://www.adb.org/documents/sri-lanka-tsunami-affected-areas-rebuilding-project>.
- [2] Ahmed, I., 2011. An overview of post-disaster permanent housing reconstruction in developing countries. *International Journal of Disaster Resilience in the Built Environment*.
- [3] Andrew, S.A. et al., 2013. The effect of housing assistance arrangements on household recovery: An empirical test of donor-assisted and owner-driven approaches. *Journal of Housing and the Built Environment*. 28(1), 17-34. <https://doi.org/10.1007/s10901-012-9266-9>.
- [4] Apurva, P. et al., 2020. Challenges in Post-Disaster Housing Reconstruction: Analysis of Urban vs. Rural Communities. *Proceedings of the Creative Construction E-Conference*. 103-110. <https://doi.org/10.3311/CCC2020-061>.
- [5] Barakat, S., 2003. Housing Reconstruction after Conflict and Disaster. *Humanitarian Policy*. [http://www.ifrc.org/PageFiles/95751/B.d.01.Housing%20Reconstruction%20After%20Conflict%20And%20Disaste\\_HPN.pdf](http://www.ifrc.org/PageFiles/95751/B.d.01.Housing%20Reconstruction%20After%20Conflict%20And%20Disaste_HPN.pdf).
- [6] Beasley, T.M., & Schumacker, R.E., 1995. Multiple regression approach to analyzing contingency tables: Post hoc and planned comparison procedures. *The Journal of Experimental Education*. 64(1), 79-93. <https://doi.org/10.1080/00220973.1995.9943797>.
- [7] CFP, 2018. Community perception report; Reconstruction, Food Security, Livelihood and Protection. *Inter-Agency Common Feedback Project, UN*.
- [8] Chang, Y. et al., 2010. Resourcing challenges for post-disaster housing reconstruction: A comparative analysis. *Building Research & Information*. 38(3), 247-264.
- [9] Chang, Y. et al., 2012. Changes in resource need for post-disaster reconstruction: A longitudinal study in China. *Building Research & Information*. 40(3), 327-336. <https://doi.org/10.1080/09613218.2012.684867>.
- [10] Daly, P. et al., 2017. Situating local stakeholders within national disaster governance structures: Rebuilding urban neighbourhoods following the 2015 Nepal earthquake. *Environment and Urbanization*. 29(2), 403-424. <https://doi.org/10.1177/0956247817721403>.
- [11] Diplomat, T., (n.d.). Nepal's Desperate Race to Rebuild. Retrieved June 12, 2020. <https://thediplomat.com/2018/04/nepals-desperate-race-to-rebuild>.
- [12] DUDBC, 2015. Design Catalogue for Reconstruction of Earthquake Resistant Houses (Vol. 1). Department of Urban Development and Building Construction, Ministry of Urban Development. <https://www.dudbc.gov.np/download/cat/13>.
- [13] Duyn Barenstein, J.E., 2006. Housing reconstruction in post-earthquake Gujarat: A comparative analysis. *Overseas Development Institute*.
- [14] Ghasemi, A., & Zahediasl, S., 2012. Normality Tests for Statistical Analysis: A Guide for Non-Statisticians. *International Journal of Endocrinology and Metabolism*. 10(2), 486-489. <https://doi.org/10.5812/ijem.3505>.
- [15] GMaLI, C., 2020. Reconstruction Update, June 15. <http://www.clpiugmali.gov.np/reconstruction-update>.
- [16] Hashimoto, S., 2016. Reconstructing Areas Affected by the Great East Japan Earthquake Disaster: Progress and Challenges, in: S. Haruyama & T. Sugai (eds.), *Natural Disaster and Coastal Geomorphology*. Springer International Publishing, pp. 133-162. [https://doi.org/10.1007/978-3-319-33814-9\\_7](https://doi.org/10.1007/978-3-319-33814-9_7).
- [17] JICA, 2013. The Study of Reconstruction Process from Large-Scale Disasters. *JICA's Support for Reconstruction*. <https://openjicareport.jica.go.jp/pdf/12127395.pdf>.
- [18] Kennedy, J. et al., 2008. The meaning of 'build back better': Evidence from post-tsunami Aceh and Sri Lanka. *Journal of Contingencies and Crisis Management*. 16(1), 24-36.
- [19] Khadka, B., 2020. Mud masonry houses in Nepal: A detailed study based on entire reconstruction scenario in 31 earthquake-affected districts. *Structures*. 25, 816-838. <https://doi.org/10.1016/j.istruc.2020.03.042>.
- [20] Kotani, H., & Honda, R., 2019. Effective combinations of information content and channels for the post-disaster reconstruction of rural housing: A case study of the 2015 Gorkha Nepal Earthquake. *International Journal of Disaster Risk Reduction*. 39, 101118. <https://doi.org/10.1016/j.ijdr.2019.101118>.

- [21] Lam, L.M., & Kuipers, R., 2019. Resilience and disaster governance: Some insights from the 2015 Nepal earthquake. *International Journal of Disaster Risk Reduction*. 33, 321-331. <https://doi.org/10.1016/j.ijdrr.2018.10.017>.
- [22] Limbu, B. et al., 2019. Reconstructing Nepal: Post-earthquake experiences from Bhaktapur, Dhading and Sindhupalchowk.
- [23] Lyons, M., et al. (eds.), 2010b. Building back better: Delivering people-centred housing reconstruction at scale. Practical Action Pub
- [24] Lyons, M., et al. (eds.), 2010b. Building back better: Delivering people-centred housing reconstruction at scale. Practical Action Pub.
- [25] McHugh, M.L., 2013. The Chi-square test of independence. *Biochemia Medica*. 143-149. <https://doi.org/10.11613/BM.2013.018>.
- [26] NPC, 2015a. Nepal Earthquake 2015: Post Disaster Needs Assessment Vol. A: Key Findings. National Planning Commission, Government of Nepal.
- [27] NPC, 2015b. Nepal Earthquake 2015: Post Disaster Needs Assessment Vol. B: Sector Reports. National Planning Commission, Government of Nepal.
- [28] NRA, 2015. Grant Distribution Guideline. National Reconstruction Authority, Government of Nepal.
- [29] NRA, 2016. Private Housing Reconstruction, Technical Inspection Guideline. National Reconstruction Authority, Government of Nepal. [https://www.preventionweb.net/files/63760\\_fnasq59djhd3wuk-o4ubh20180813.pdf](https://www.preventionweb.net/files/63760_fnasq59djhd3wuk-o4ubh20180813.pdf).
- [30] NRA, 2017. Rebuilding Nepal. National Reconstruction Authority, August, 2017. <http://nra.gov.np/en/content/bulletins/0>.
- [31] NRA, 2019a. Rebuilding Nepal. National Reconstruction Authority, December, 2019. <http://nra.gov.np/en/content/bulletins/0>.
- [32] NRA, 2019b. Rebuilding Nepal. National Reconstruction Authority, October 2019. <http://nra.gov.np/en/content/bulletins/0>.
- [33] NRA, 2020. Media Center—Notice. National Reconstruction Authority, May 31. <http://www.nra.gov.np/np/content/noti/0>.
- [34] NRA MIS, (n.d.). EHRP MIS System. Retrieved June 2, 2020. <https://ehrpmis.nra.gov.np/>.
- [35] Sadiqi, Z. et al., 2012. Rebuilding housing after a disaster: Factors for failure, in: F. Yamada & R. Kakimoto (eds.), *Proceedings of the Disaster Management 2012: The 8th Annual Conference of International Institute for Infrastructure, Renewal and Reconstruction (IIIRR)*. pp. 292-300. <http://www.civil.kumamoto-u.ac.jp/kakimoto/iiirrShahnaz>
- Arshad, S.A., 2013. *Rural Housing Reconstruction Program Post-2005 Earthquake*. The World Bank, 1818 H Street, N.W. <https://documents.worldbank.org/en/publication/documents-reports/documentdetail>.
- [36] Siriwardena, N. et al., 2010. Managing stakeholder expectations of post-disaster housing reconstruction projects in Sri Lanka. University of Salford, UK, Issue Published Paper.
- [37] Solutions, D. 2019. Lessons Learned from Post-earthquake Policy in Nepal; Guidance for Further Housing, Land and Property Disaster and Reconstruction Law and Policy Reform. Displacement Solutions.
- [38] Steinberg, F., 2007. Housing reconstruction and rehabilitation in Aceh and Nias, Indonesia – Rebuilding lives. *Habitat International*. 31(1), 150-166. <https://doi.org/10.1016/j.habitatint.2006.11.002>.
- [39] Survey Department, (n.d.). Shapefile (GIS Data) for Political and Administrative Map of Nepal. Retrieved May 27, 2020. <http://dos.gov.np/download/news-events/shapefilegis-data-for-political-and-administrative-map-of-nepal>.
- [40] Vahanvati, M., & Mulligan, M., 2017. A new model for effective post-disaster housing reconstruction: Lessons from Gujarat and Bihar in India. *International Journal of Project Management*. 35(5), 802-817. <https://doi.org/10.1016/j.ijproman.2017.02.002>.





## Household Level Construction Cost and its Management in Rural Housing Reconstruction in Nepal

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*Keywords: Housing Reconstruction Cost, Loan, Financial Burden.*

### Abstract

This paper is based on the assessment of construction cost and its management during the housing reconstruction after the 2015 Mw 7.8 Gorkha, Nepal Earthquake. The research aims to find the cost of a reconstructed house and the management of finances. By documenting the housing reconstruction cost in Gorkha and Sindhupalchowk, this paper compares it with the preference of structure type, caste/ethnicity, and gender. The comparison shows that the average construction cost was NRs. 681,000, which is more than double the government's housing grant. Among respondents 47.10 percent of households preferred the Stone Masonry in Mud Mortar (SMM), a lower-cost structure. However, the cost of SMM still exceeded the government grant and required the households to seek loans to complete their houses. These loans came from the informal sectors. The average loan amount was about NRs. 288,000 and the average interest on the loan was 21.85, which was higher than the formal sectors. The study has recommended making formal sector loans accessible to the rural people during similar undertakings to reduce the financial burden, and to also enhance the capacity of Dalit and Janajati households to pay back the loan.

### Introduction

The 2015 Mw 7.8 Gorkha, Nepal Earthquake resulted in damage of almost a million houses, and more than 900,000 families were roofless (UNDP, 2019). The Center for Disaster Management and Risk Reduction Technology (CEDIM et al., 2015) reported that the total loss in the economic sector as being in the order of US\$ 10 billion, which is roughly half of Nepal's GDP. Housing damage accounted for more than half of the total loss (Comerio, 1997) and damage caused by the

earthquake was expected to have a major socio-economic impact on people and communities in Nepal in the long-run (Goda et al., 2015). This situation was especially true for the poorest and most vulnerable, who comprised the largest population in rural areas, and also those who had been affected disproportionately (Paul et al., 2017).

It was quite clear that the large-scale destruction of houses, primarily due to the seismic vulnerability of mud mortar houses – the most dominant of structures in rural areas, needed a significant amount of financial

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resources for housing reconstruction (NPC, 2015). In addition, building a new house, despite cost-effective solution like SMM, can be expensive as resilient components are added (Chang et al., 2010; Twigg, 2006; UNDP, 2019). Not only structural factors, the reconstruction itself was also financially challenging due to the difficult geographical situation of the affected areas. Since, the majority of the affected area fell in the hilly region (LRMP Nepal, 1986; Mainali & Pricope, 2017), the communities had some common characteristics and socioeconomic conditions. These included poor road accessibility, and insufficient availability of water and local construction material all of which contributed towards making the construction process more costly. This explained why the cost of building a house during peak reconstruction periods significantly exceeded pre-disaster levels, with higher costs of building materials and worker wages (Chang et al., 2010).

The owner-driven reconstruction approach adopted by the National Reconstruction Authority (NRA) to support the affected people, placed the responsibility of rebuilding and the financial arrangement on the household themselves (NPC, 2015). The financial support was also complemented by technical support (NPC, 2015). The government supported household with NRs. 300,000 handed over to affected households in three tranches following technical verification in accordance with the Build Back Better (BBB) policy (NRA, 2015). The question here is whether or not the government grant was economically efficient? (Freeman, 2004). The tentative estimate of building a two-room house, of around 300sqft and constructed with locally available stone and mud mortar, required at least NRs. 400,000 (including the earthquake resilient elements recommended in the technical inspection guidelines) (Bothara et al., 2016). Another study by Housing Recovery and Reconstruction Platform (HRRP, 2017) reported that the median cost of house construction, considering all types of building structures, was NRs. 700,000.

The government expected the households would contribute the additional resources required. On the fund-raising side, the government had tried to generate

resources in a way that would keep the debt ratio within a manageable level, and use grant assistance to the extent possible (NPC, 2015). The government had also approved a subsidy on the interest rate through the Subsidized Loan Policy Guidelines 2075 with a condition that bank and financial institutions should not exceed two percent of their base rate. The government had subsidized five percent of the total interest rate and the household would bear the remaining as a soft loan for housing reconstruction. However, the guidelines were not in place immediately and more than half of the total households had obtained loans to reconstruct houses at the average interest rate of 23 percent. (HRRP, 2017, 2019). Further, local branches of private commercial banks did not accept the process of group guarantees or soft loans, as they were not sure if the central government would pay back, and deliver on its commitment. There was a general belief the earthquake-affected families would receive only the first installment, which they would use for paying existing debts and construct weak temporary shelters, or would spend the money to meet livelihood needs. These challenges prevented many earthquake victims, especially the economically and socially deprived, from accessing bank loans or drawing from other resources. They also feared being trapped in debt traps, especially if they borrowed from informal lenders (The Asia Foundation, 2016).

Other challenging factors faced in housing reconstruction by households were the limited financial capacity, and therefore needed financial protection (Freeman, 2004). Bothara et al. (2016) added that accessibility to modern construction materials, information, skills, and technology also affected housing reconstruction. Additionally, the complete dependency of households in rural areas on agriculture, and the lower cash flows forced a major portion of the male population to migrate overseas for jobs (Bothara et al., 2016). This not only created a deficiency in skilled labor, technicians and workers (Manandhar, 2016) but also meant that the women-led households, that were already overloaded with daily chores (NPC, 2015) and agricultural work (Bothara et al., 2016), had to take responsibility

for reconstruction. Finally, the housing type preferences also depended on caste/ethnicity (CBS, 2014c) as resources availability widely varied among different caste/ethnic groups (Massey et al., 2010).

The constraint of resources (Tukel & Rom, 1998) and limited alternatives (Russell, 2005) for housing reconstruction leads to cost overruns (Chang et al., 2010). Similarly, cost surge (Jayasuriya & McCawley, 2008; Steinberg, 2007) was found to be a critical factor that determined successful completion of post-disaster housing reconstruction (Chang et al., 2012).

The household-level construction cost and its management remain important issues. However, there is a dearth of research looking at construction costs during the period of housing reconstruction. Most of the previous studies were only snap-shots of the housing issue or generated high-level lessons and experiences from disaster (Chang et al., 2012). This study has attempted to contribute an in-depth understanding of construction cost and its management. It has analyzed how households managed the additional cost required for reconstruction; whether they used a loan with an interest, or their own money? Accordingly, the results can be used as an indicator of cost demand for housing reconstruction in rural areas. The study has also reported on the investment capacity of the rural household for reconstruction, and has recommended necessary support for the eligible households to reduce the financial burden of post-disaster reconstruction.

The main objective of this paper was to find the cost of a reconstructed house and its financial management, which is affected by structure, caste/ethnicity, and gender. Another objective of this paper was to identify the effects of caste/ethnicity and gender on loan and interest rate, which households had used to bridge the gap between actual construction cost and the grant provided by the government.

### Effects on construction cost

Housing reconstruction cost is influenced by material and design specifications for building type (Twigg, 2006) and low-cost structures are the most preferred

choices (Twigg, 2006). Increasing construction cost determines the type of housing reconstruction after a disaster (Chang et al., 2012). In this paper we examine the impact of housing structure type on housing reconstruction cost.

H1. Housing reconstruction cost is affected by the type of structure.

Based on the cultural practices, the preference of building type depends on caste/ethnicity (CBS, 2014b) because the resources available vary widely among different caste/ethnicity groups (Massey et al., 2010).

H2. Housing reconstruction cost is affected by caste/ethnicity.

The housing construction cost also differs by gender; gender equality was identified as one the important requirement by the government (NPC, 2015) as failure to incorporate gender issues could hinder the success of the recovery process (Delaney & Shrader, 2000). This study also assesses the difference in reconstruction capacity among male and female-headed households.

H3. Housing reconstruction cost is affected by the gender of the household head.

### Effects on the loan amount

The government had expected the construction cost will be managed by households (NPC, 2015). Past studies show that the construction cost can be higher after disasters than that before the disaster and also vary with structure types as resilient components are added. This suggested existence of a clear gap between the housing grant and actual construction cost. Households fulfilled this gap by using their own money or by taking loans. However, the opportunity and resources of all households are never the same (Massey et al., 2010). Lenders often differentiate the loan provided to households based on repayment capacity (Yadav et al., 1992). This capacity can be assumed to vary also by gender and social status. Hence, assumption were that the capacity to obtain a loan differed based on cast/ethnicity and gender of the household heads.

H4. The loan amount for housing reconstruction is affected by structural type.

H.5. The loan amount for housing reconstruction is affected by cast/ethnicity.

H.6. The loan amount for housing reconstruction is affected by the gender of the household head.

Rural people prefer to obtain loans from easily accessible means such as the informal sector, comprising of systems that are outside the official institutional framework (Canagarajah & Sethuraman, 2001) such as neighbors, relatives, and friends. Similarly, Besley et al. (2001) found that loans were taken from informal sources rather than bank and cooperatives in the rural areas of Nepal. Yadav et al. (1992) added that the availability of formal sector loans depended on collateral. Therefore, the asset-poor were forced to take loans from informal lenders, often at a higher interest rate. These situations suggest that the loan amount and its interest rate would vary based on who the lender was.

H7. The loan amount for housing reconstruction is affected by major lenders.

H8. The interest rate for housing reconstruction is affected by major lenders.

### Effects on Interest rate

The difference in interest rates among various lenders was quite apparent from previous studies. Yadav et al. (1992) added that the capacity of repayment was an important factor and in turn, affected the interest rates. So, assumptions can be made that interest rates varied for households based on their social status and gender.

H9. The interest rate for housing reconstruction is affected by caste/ethnicity.

H10. The interest rate for housing reconstruction is affected by the gender of the household head.

### Methodology

The research focuses only on the financial management of housing reconstruction cost, including material procurement cost, transportation cost (Cho et al., 2001), and labor cost (skilled and non-skilled), which is higher after disasters compared to the normal (Chang et al., 2010; Lyons, 2009; Steinberg, 2007). Sources for

financing construction cost in Nepal included government grant, own money and loan money with varied interest rates depending on the source from where credit was obtained such as the formal sector (bank and cooperative) and the informal sector (neighbors, relatives, and others). The distance from the market was not considered even though the cost of housing reconstruction is determined by accessibility. This study did not also consider the sources and capacity of households to pay back the loans.

The financial burden on households during house reconstruction after the earthquake is considered to be the extra amount or the amount that they had to add over the government grant. We had assumed that a household would use the government grant to build the house and seek loans if the grant was not enough. This additional investment would be made through personal resources or through loans. The loan amount obtained by the household and the interest rate has been used to describe the debt situation. Data for this purpose was obtained from two of the most earthquake-affected districts, Gorkha and Sindhupalchowk. The housing reconstruction cost and the sources of financing the construction cost have been documented at the household level and compared with the preference of structure type, and analyzed in terms of gender and caste/ethnicity.

### Data collection

The EHRP database was the main source of data, which was surveyed, maintained, and updated biweekly through combined efforts of the project's mobile masons, engineers, and social mobilizers. The database contained approximately 100 types of information on each household. The data included demographic information, and that on location and construction (structural typology, cost, loan, and interest rates). This database covered 95,117 beneficiaries (households) from 109 wards; 91 in Sindhupalchowk and 18 in Gorkha. The database was limited to 12 municipalities of Sindhupalchowk and five of Gorkha. Household heads were interviewed to collect the data.



The interview contained a series of questions on how the household heads had managed the construction cost, loan, the interest rate, and lender along with the structural typology and other general demographic information like caste/ethnicity, gender, etc.

Independent variables identified were gender, caste/ethnicity, structural typologies, and lender source while the dependent variables were total construction cost, loan amount, and interest rate. The same categorization of caste/ethnicity used by the government of Nepal (CBS, 2014a) was used. We had five caste/ethnic categories Brahmin-Chhetri (24,808 in sample), Dalit (6,750), Janajati (36,940), Newar-Thakali (8,234), and Others (3,142) among respondents. Among them Brahmin, Chhetri, Newar, and Thakali were considered with greater access to facilities. The others category included all other caste/ethnicity groups not in the five categories above or who did not want to mention their caste/ethnicity. Major lenders of loan were categorized as bank, cooperative, relative, neighbor, and others. The others category represented sources like friends, village landlords, etc. Similarly, the type of houses used in the study were those provided by the Ministry of Urban Development (DUDBC, 2015, 2017; NRA, 2017). The house categories were: i) Stone Masonry

with Mud Mortar (SMM), ii) Brick Masonry with Mud Mortar (BMM), iii) Stone Masonry with Cement Mortar (SMC), iv) Brick Masonry with Cement Mortar (BMC), v) Reinforced Cement Concrete (RCC), vi) Hybrid, a type of house that use two different techniques i.e. stone and brick, stone and wood, etc., vii) Light frame steel structure, viii) Light frame timber structure and ix) Others – it included other types of buildings that did not fall in the above-mentioned categories. Data up to April 2020 on the 79,874 sample households were analyzed to compare structural preferences, caste/ethnicity, gender, and total construction costs. Among 79,874 households, 63,672 were of male-headed households and 16,198 were female-headed and four were headed by heads belonging to the third gender. Loan and interest analysis was done only with data with loan and interest information, 44,822 and 48,062, respectively.

#### Method of analysis

The research was descriptive and inferential. The initial cleanup of the database included looking at households, who had completed house construction and removing the data with missing information. Further,

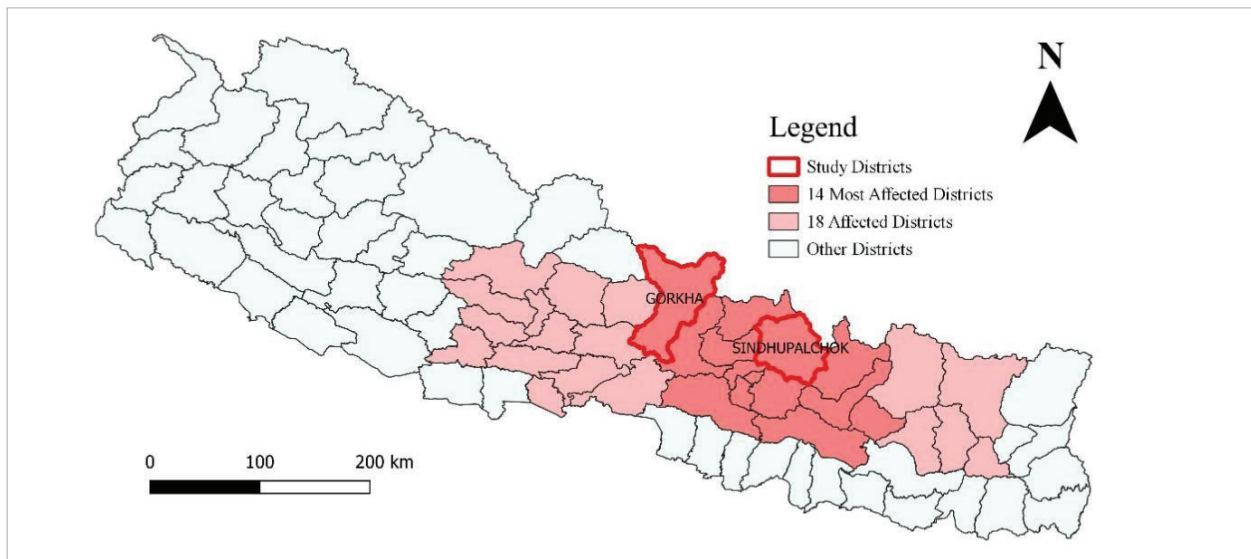


Figure 1. Study area and other earthquake affected districts in the map of Nepal (NPC, 2015; Survey Department, 2020)

interquartile range rule with resistant factors of 1.5, 3 (Hoaglin et al., 1986), and 2.2 (Hoaglin & Iglewicz, 1987) were used to identify and remove outlier data, with a very high construction costs in each structure type individually to ensure a refined final database. The research analyzed categorical independent variables, with unequal sample sizes, against the dependent numerical variables. Hence, it was not possible to justify the differences observed in the means between the variable categories only through descriptive statistics. Therefore, the research used Analysis of Variance (ANOVA) and its post hoc test in identifying significant results as a part of the inferential analysis. The first step was to refer to Levene's F test for homogeneity of variance. A significant result ( $p < 0.05$ ) for Levene's F test meant that the variance was not homogeneous or equal. In such cases, we referred to a more robust Welch's F test. However, for categories that did not produce a significant result ( $p > 0.05$ ) for Levene's F test, that is the variances were more or less equal, we referred to the standard ANOVA table. The second step was to look at significant results for the ANOVA test or Welch's F test. A significant result ( $p < 0.05$ ) meant that there was a significant difference between the variances of categories. However, it did not reveal which category varied more. For this, Games Howell's post hoc test was used – when the variances are not equal – to elaborate the category that varied significantly.

## Result and discussions

### Construction cost and management

The average construction cost of a house, among 79,874 households, was NRs 681,138 (Figure 3). In other words, the people invested almost more than double the amount of the housing grant provided by the government. This was similar to the findings by (HRRP, 2017). The housing reconstruction program was owner-driven and the households had managed the additional investment, irrespective of the financial burden on them.

The government grant of NRs. 300,000 was enough

to build only 17 percent of the surveyed houses (Figure 2). It was possible with low-cost SMM and BMC houses that were smaller in size, used construction material from damaged buildings, and the labor was also provided by the owner-households. The remaining 83 percent households required additional investments either from personal finances or loans or both to complete and this resulted in a financial burden on those households. Forty-four percent households required both personal investment and loans to complete their houses over the government support (Figure 2). Similarly, 12 percent households had used only loans over the government support. Therefore, about 56 percent households were facing the burden of loans. Finally, one percent of the surveyed houses did not use the government grant but rebuilt houses either through a loan or by drawing from personal finances – others in Figure 2.

### Construction cost and building type preference

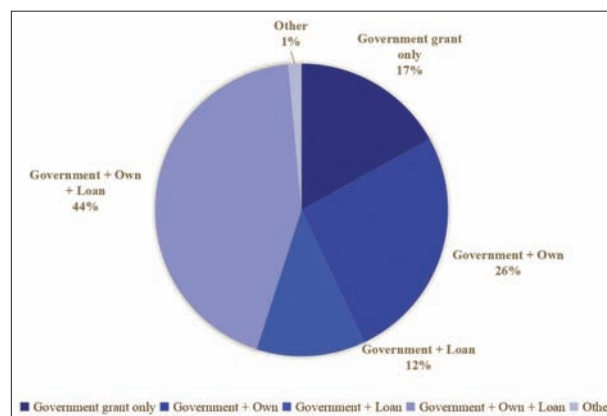


Figure 2. Distribution of financial burden of construction

A Games Howell's post hoc test was performed between total construction cost and building structure as Levene's F test had revealed that the homogeneity of variance assumption was not met ( $p < 0.001$ ) and also because Welch's F test,  $F(8, 292.98) = 3539.86, p < 0.001$ , indicated that there was a difference in the mean construction cost between the different structures, proving H1 to be correct. The data was normally distributed due to the central limit theorem ( $N=79,874$ ) (Ghasemi

& Zahediasl, 2012). The one-way ANOVA test revealed that RCC (M=NRs. 1,520,501, SD=751,458) houses had a significantly higher construction cost compared to all building structures. While SMM (M=NRs. 475,402, SD=163,888) houses had significantly lower cost than BMC houses (M=NRs. 635,833, SD=247,042), Hybrid (M=NRs. 628,846, SD=258,155), Light Frame Timber (M=NRs. 495,968, SD=186,424), Others (M=NRs. 545,871, SD=228,840), RCC and SMC (M=NRs. 596,471, SD=218,671). However, even though the average cost of SMM was the lowest among all types, there was no significant difference between the mean construction cost of SMM and Light Frame Steel (M=NRs. 494,444, SD=262,277) and BMM (M=NRs. 526,667, SD=268,506) structures.

The cost of the SMM structure was the lowest, hence, Figure 4 shows that SMM was the most preferred building type with 47.10 percent households constructing such houses. The other reason for this was the difficulty in transporting modern construction materials while stone and mud were easy available in rural areas. This

was followed by the BMC structure, which was preferred by 32 percent households because the cost was comparatively lower than the RCC, SMC, and BMC structures. Another reason was the comparatively technique to build such structures. The third most preferred building type was RCC (14.10%), which was the most expensive structure compared to other structures, followed by SMC and other categories (2.9% each). BMM was the least preferred building type because mud mortar was used in structures where transportation of cement and sand was difficult. However, where bricks could be transported easily, the households usually preferred to also use cement and sand. It appeared that the people have determined the type of structure based on their investment capacity.

The average construction cost of all building structures except RCC was below the total average. The data also consisted of RCC houses that were built within the government grant of NRs. 300,000. Few of these were single-room structures and there was no clear reason for the others. Overall, the number of such anomaly

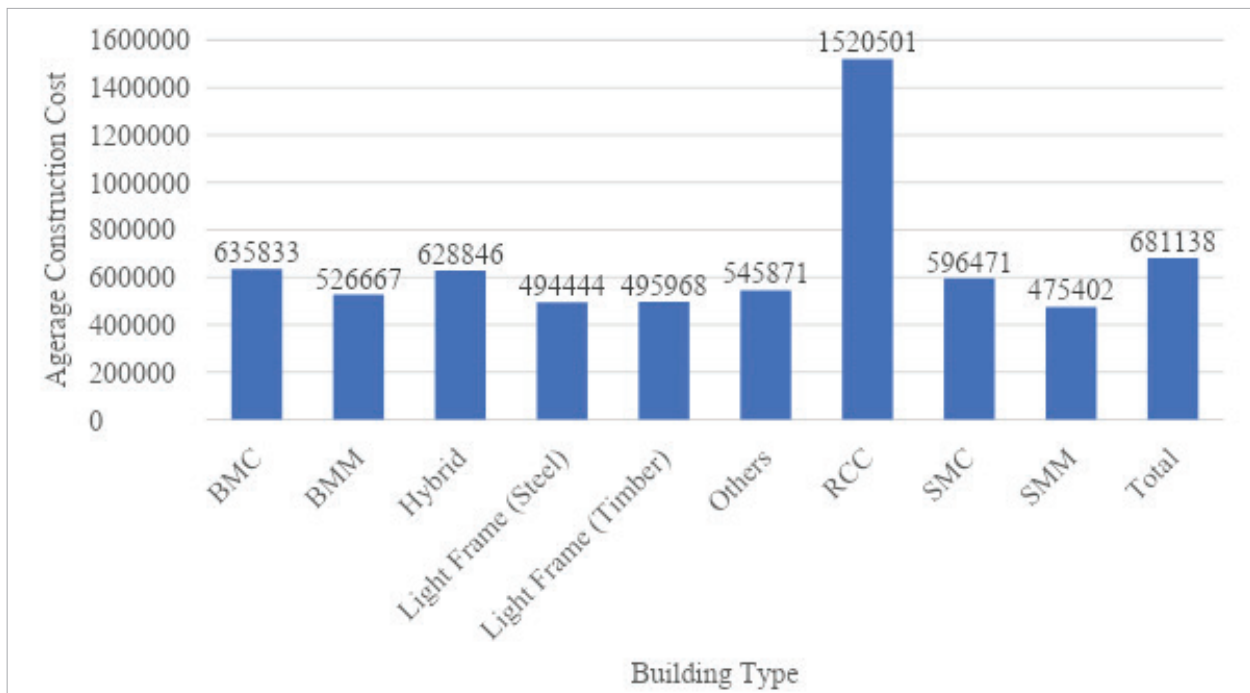


Figure 3. Average construction cost per building type

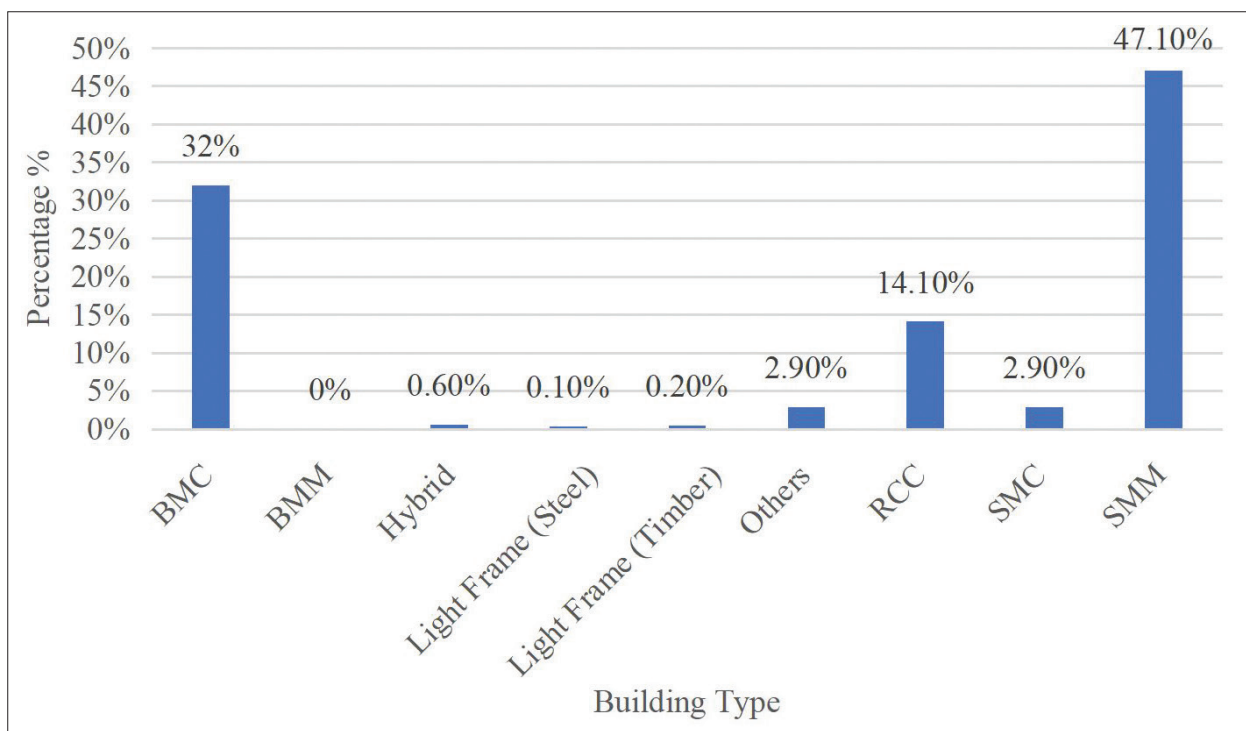


Figure 4. Preference of building type

was pretty small to make any major differences to the average. Also, the number of BMM structures was only 15. Therefore, it can be concluded that this type of structure, even though less expensive, was not preferred by the households of Sindhupalchowk and Gorkha.

Figure 5 shows that the proportion of total households covered by only the government grant was lower than the proportion of households not covered by only the grant.

#### Total construction cost and caste/ethnicity

Levene's F test between total construction cost and caste/ethnicity revealed that the homogeneity of variance assumption was not met ( $p < 0.001$ ) and the Welch's F test,  $F(4, 14806.49) = 222.08$ ,  $p < 0.001$ , indicated that there were differences in the mean construction cost between the different caste/ethnic groups, which also proved H2 as true. The data was normally distributed

due to the central limit theorem ( $N=79,874$ ) (Ghasemi & Zahediasl, 2012). The Games Howell's post hoc test between total construction cost and caste/ethnicity revealed that there were significant differences between the mean construction cost of all caste/ethnic groups, with  $p < 0.001$ , except for the Newar-Thakali ( $M=NRs. 776,657$ ,  $SD=625,371$ ) and Others ( $M=NRs. 746,865$ ,  $SD=502,961$ ). The average cost of houses was significantly lowest for Dalits ( $M=NRs. 581,341$ ,  $SD=341,377$ ). The average cost of houses constructed by Newar-Thakali households were significantly highest (NRs. 776,657), except for the Other groups because even though the mean construction cost was higher for the Newar-Thakali, the result was not significant ( $p=0.65$ ). Figure 6 shows a similar average construction cost for Brahmin-Chhetri and Newar-Thakali households and lower for Janajati and Dalit households.

In terms of caste/ethnicity, Brahmin-Chhetri and Newar-Thakali households had invested more than the Dalits and Janajati households. The social stratification



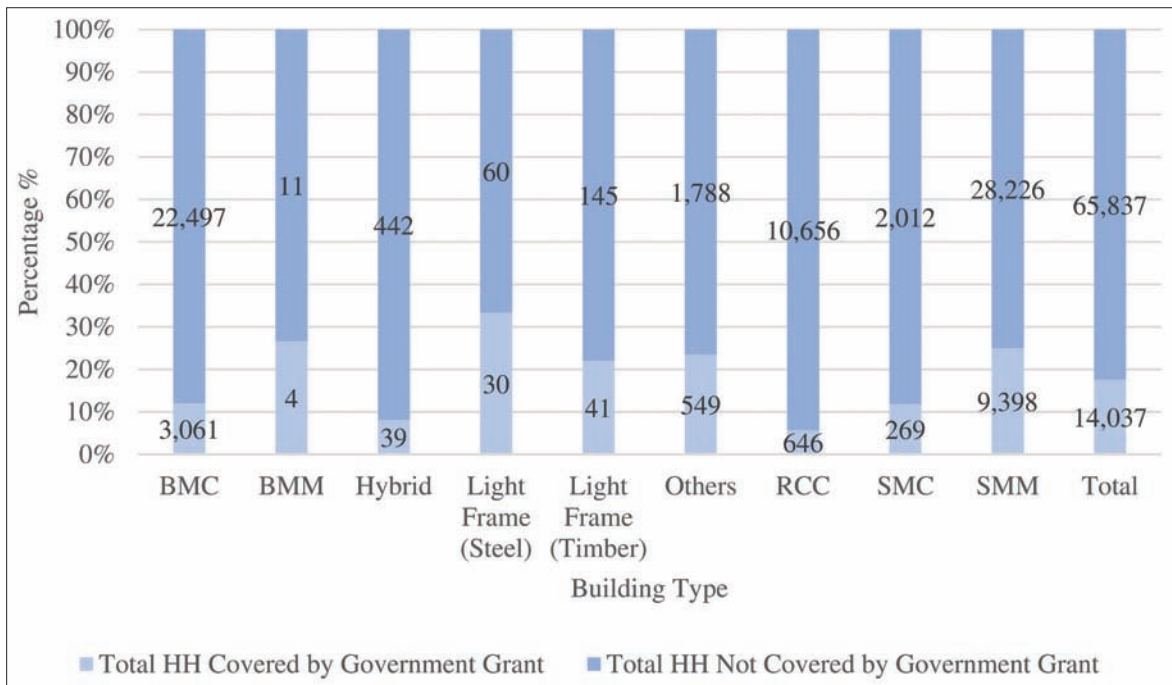


Figure 5. Households built using only the government grant

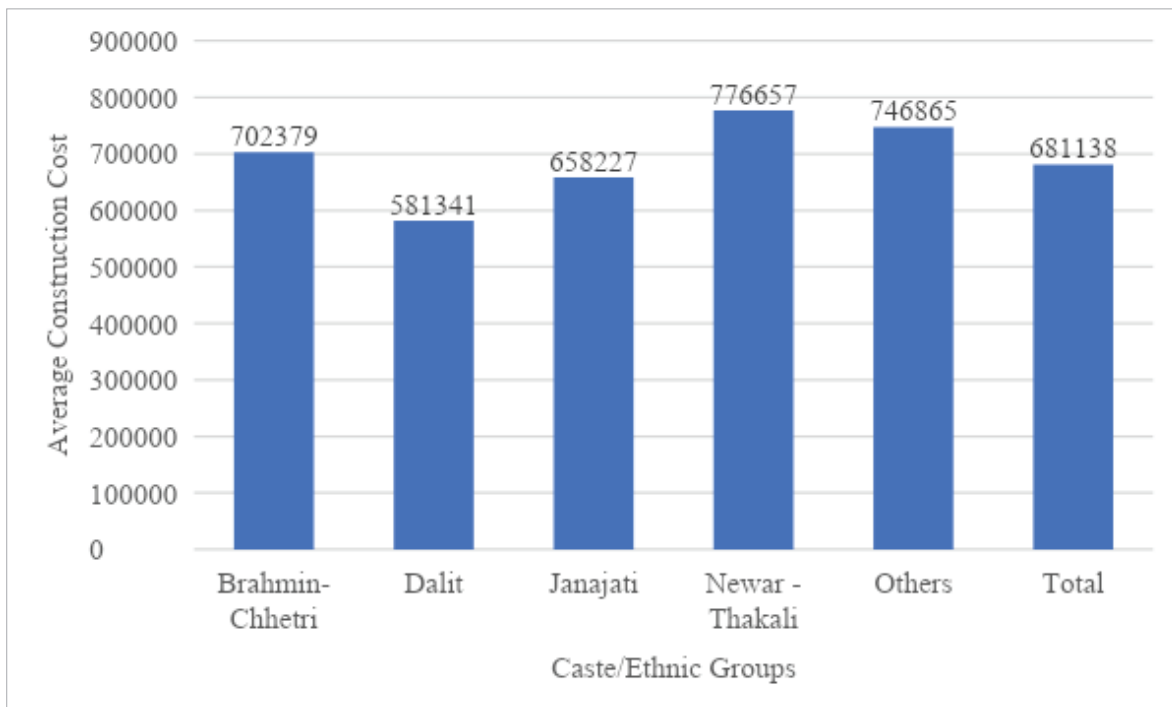


Figure 6. Average construction cost of different caste/ethnic groups

shows that the financial capacity of Brahmins, Chhetris, Newars, and Thakalis was higher than the Dalits and Janajatis (Bennett et al., 2008). The financial capacity of different caste/ethnic groups was therefore also reflected in the investment for housing reconstruction.

### Total construction cost and gender

The average construction cost of male-headed households (M=NRs. 687,918, SD=491,104) was significantly higher than that of female-headed households (M=NRs. 654,519, SD=467,217), as revealed by the one-way ANOVA Welch's F test,  $F(2, 8.01) = 30.93$ ,  $p < 0.001$ . This showed H3 to be true, that is, the effect of gender was significantly different in the cost of house reconstruction, as the average construction cost of the houses of male-headed households was higher than that of female-headed households. This result showed gender was associated with investment capacity of the households.

### Loan amount

Figure 7 shows that the average loan amount of the households was NRs. 288,728. The average amount of loans taken by the households were almost equal to the government grant. Of the total surveyed households, 56.11 percent (44,822) had taken loans to build their houses. The result showed that a substantial number of households had obtained a loan for building houses. The Inter-Agency Common Feedback Project (CFP, 2018) had predicted that significant number of households who had completed construction would have taken a loan.

### Loan amount and structure

Similar to the construction cost, the average loan amount differed for various structures. Levene's F test revealed that the homogeneity of variance assumption was not met ( $p < 0.001$ ) and so did the Welch's F test,  $F(8, 69.88) = 1449.68$ ,  $p < 0.001$ , indicating that there were differences in the mean loan amount between the different structural typologies, which showed that H4

was correct. Again, the data was normally distributed due to the central limit theorem ( $N=44,822$ ) (Ghasemi & Zahediasl, 2012). The Games Howell's post hoc test revealed that the average loan amount for RCC (M=NRs. 667,660, SD=451,229) was significantly the highest among all the structures with  $p < 0.001$  for all and  $p < 0.05$  for BMM (M=NRs. 200,000, SD=122,474). In case of BMC structure (M=NRs. 236,015, SD=159,459), the average loan amount was significantly higher than that of SMM (M=NRs. 162,861, SD=103,352) and others (M=NRs. 206,135, SD=147,143). Even though BMC structures had a higher average loan amount compared to BMM, hybrid (M=NRs. 233,482, SD=159,484), Light Frame Timber (M=NRs. 228,070, SD=131,617), and SMC (M=NRs. 224,768, SD=140,395) structures, the ANOVA test did not yield any significant result. The most preferred structure SMM ( $n=18326$  ie. 41%) had the least amount of average loan, at  $p < .001$  for BMC, hybrid, others, RCC, and SMC and at  $p < .05$  for light frame steel and timber, except for BMM where the test was not significant even though the averages were lower. The average loan amounts for all other building structures other than RCC were below the average.

The average loan amount was highest for households with RCC houses and lowest for SMM houses. As the investment for RCC was higher and SMM lower. Therefore, the households with higher investment capacity tended to seek more loans than the households with lower investment capacity. The average loan amounts of all other building structures except RCC was below the total average because of the construction cost of these structures.

### The loan amount and caste/ethnicity

A Games Howell's post hoc test was performed between the average loan amount and caste/ethnicity as the Levene's F test revealed that the homogeneity of variance assumption was not met ( $p < 0.001$ ) and also Welch's F test,  $F(4, 8355.58) = 159.78$ ,  $p < 0.001$ , indicated that there was a difference in the mean loan amount between the different caste/ethnic groups; hence, confirming H5. The data is normally distributed

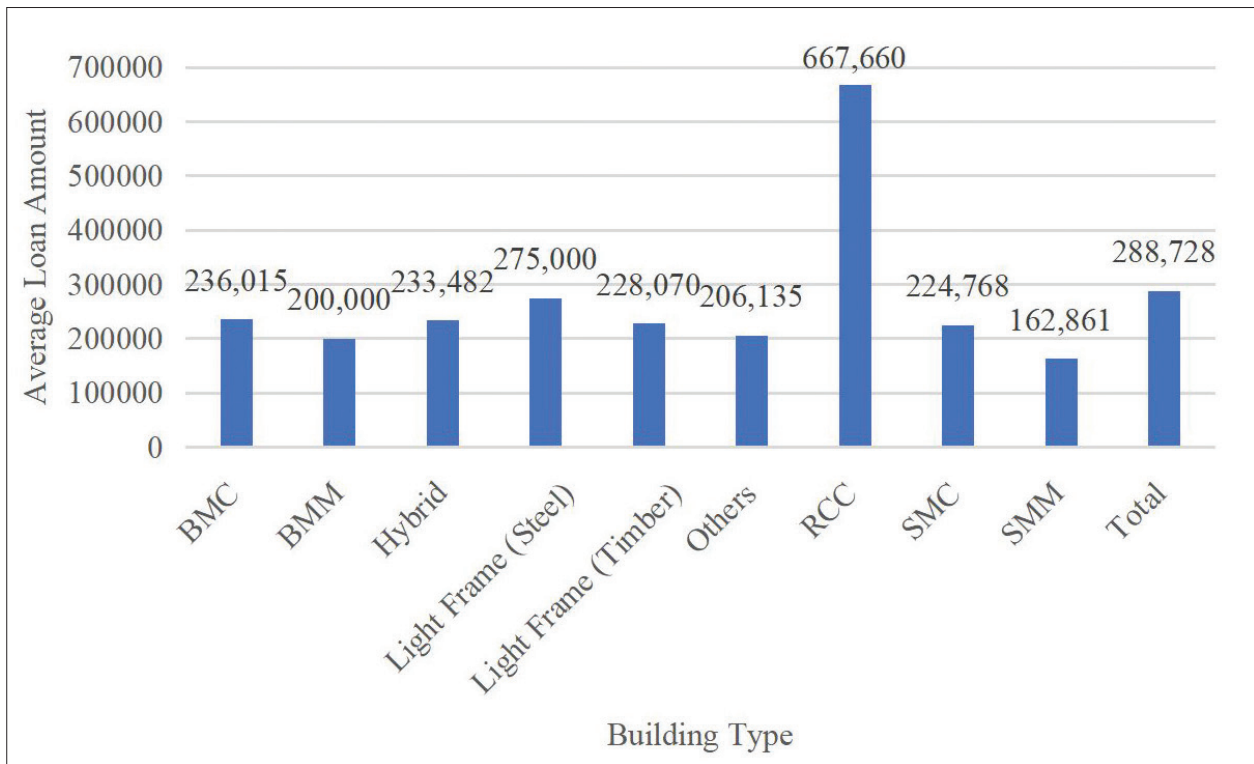


Figure 7. Average loan taken to build a building type structure

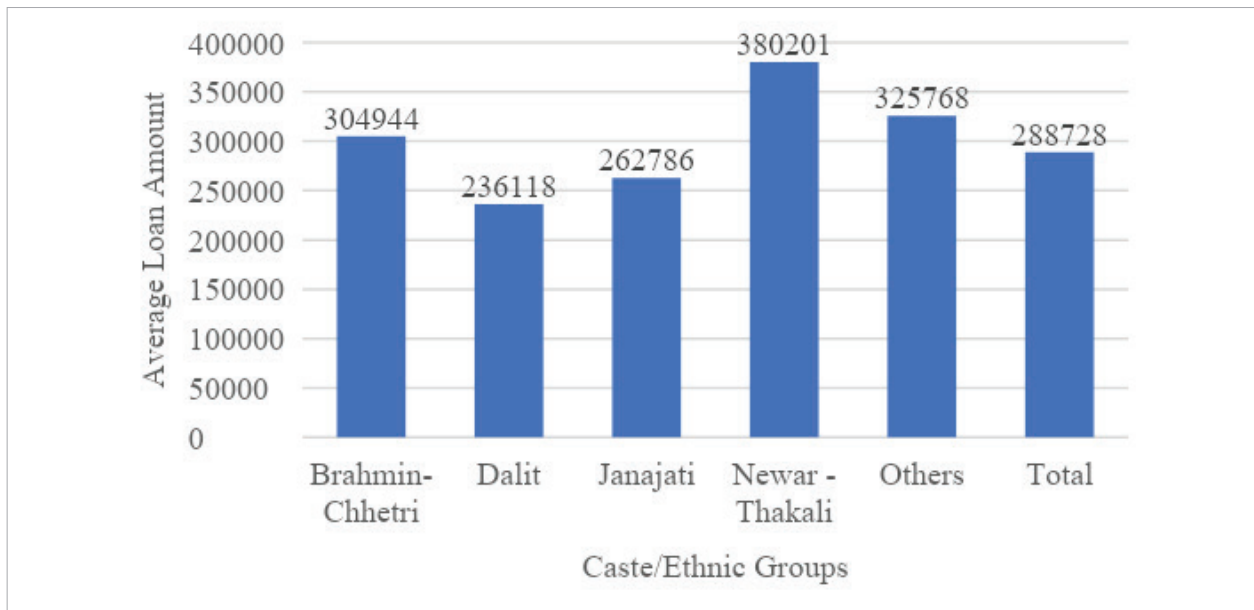


Figure 8. Average loan taken by different caste/ethnic groups

due to the central limit theorem ( $N=44,822$ ) (Ghasemi & Zahediasl, 2012). The ANOVA test revealed that the average loan that Newar-Thakali ( $M=NRs\ 380,201$ ,  $SD=399,658$ ) obtained to construct their houses was significantly higher than all other castes/ethnic groups, as opposed to Dalits ( $M=NRs\ 325,768$ ,  $SD=317,108$ ) whose average loan amount was the lowest (Figure 8). This might be due to the higher average construction cost of Newar-Thakali households and the lower average construction cost of Dalit households. Similarly, Brahmin-Chhetri ( $M=NRs\ 304,944$ ,  $SD=316,045$ ) had significantly higher average loans compared to Janjati ( $M=NRs\ 262,786$ ,  $SD=261,016$ ) but was significantly lower than average loan amount the others ( $M=NRs\ 325,768$ ,  $SD=317,108$ ).

The average loan taken by Newar-Thakali households to build houses was highest while it was lowest for Dalits. This might be due to the higher average construction cost of Newar-Thakali households and the lower average construction cost of Dalit households (Figure 6).

### The loan amount and gender

The average loan taken by the males ( $M=NRs\ 291,737$ ,  $SD=299,540$ ) was significantly higher than that of females ( $M=NRs\ 276,211$ ,  $SD=294,237$ ) as revealed by the one-way ANOVA Welch's F test,  $F(1, 13325.46) = 19.34$ ,  $p<0.001$ . The Welch's F test also confirmed the last part of H6. The Welch's F test was chosen because Levene's test of homogeneity of variance failed at  $p<.05$ . Loan data was available for a total of 44,821 households of which 19.35 percent were female and 80.64 percent were male. The data were normally distributed due to the central limit theorem.

### Major lender

The Games Howell's post hoc test performed between the average loan amount and major credit provider revealed no significant difference between the major lender groups, neighbors ( $M=NRs\ 257,225$ ,  $SD=251,565$ ), others ( $M=NRs\ 254,772$ ,  $SD=257070$ ) and

relatives ( $M=NRs\ 251,496$ ,  $SD=243,766$ ). However, it was found that bank ( $M=NRs\ 618,197$ ,  $SD=517,325$ ) provided the highest average loan amount than any other group, followed by cooperatives ( $M=NRs\ 300692$ ,  $SD=517,325$ ). The post hoc test was used because Levene's F test revealed that the homogeneity of variance assumption was not met ( $p<0.001$ ); and the Welch's F test,  $F(4, 13100.03) = 392.528$ ,  $p<0.001$  indicated that there were differences in the mean loan amount between the major lenders. This confirmed the H7 hypothesis assumed above in section 1. The data was normally distributed due to the central limit theorem ( $N=44,745$ ) (Ghasemi & Zahediasl, 2012).

Figure 10 shows that the relatives were the major lenders for 33.95 percent households who had borrowed from them followed by neighbors (24.73%). Although only 6.52 percent households had borrowed from a bank, the average loan amount provided by banks was much higher than other lenders. Households that had obtained loans from informal sources like relatives, neighbors, and other sources like friends, local landlords stood at 70.6 percent.

Relatives were the major lender followed by neighbors. What this suggested is that relatives and neighbors were more reliable sources for loans, and lenders also trusted the borrowers based on the relationship. The majority of households had obtained loans from informal sources like relatives, neighbors, and other sources like friends and landlords (Besley et al., 2001).

### Interest rates

The average interest rate of loans received by households was 21.85 percent, which was higher than the loan provided by the formal lenders.

### Interest rates and major lender

An ANOVA test was carried out between loan interest provided by different lender groups to determine whether there was any significant difference in the interest rates. The Levene's F test revealed that the homogeneity of variance assumption was not met



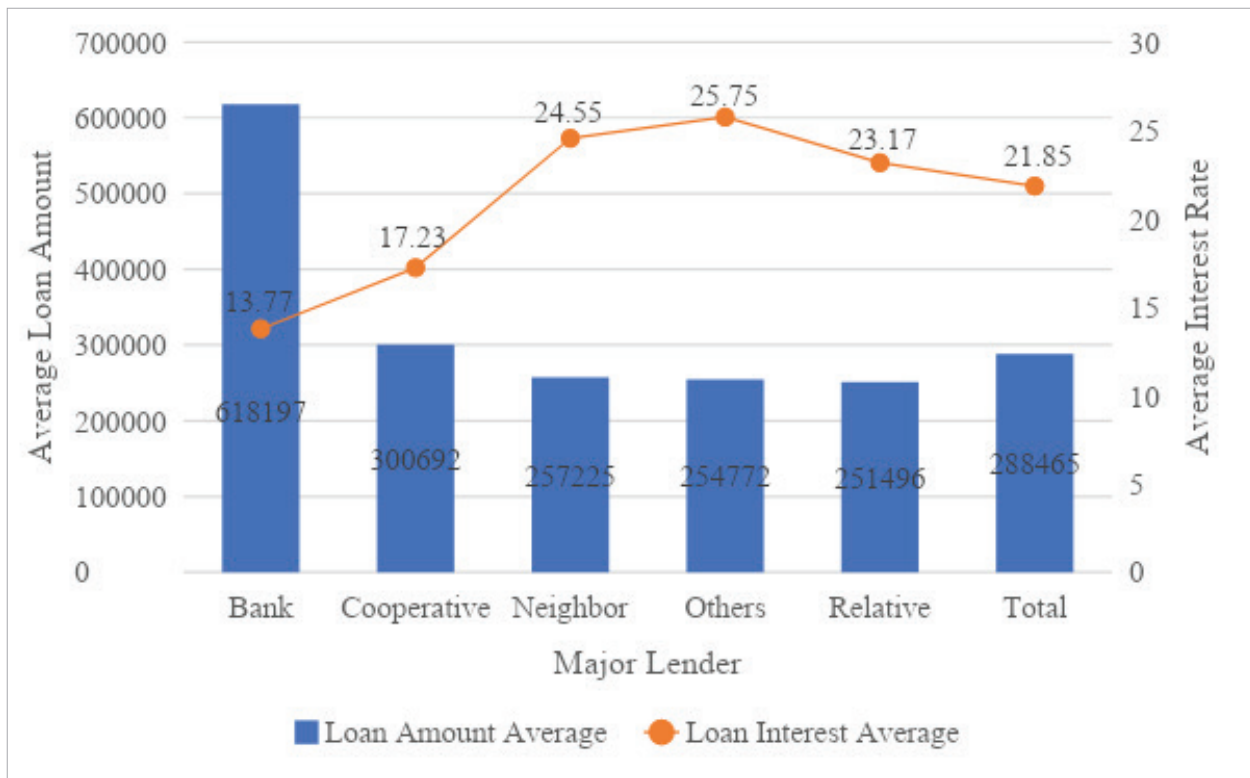


Figure 9. Average loan amount and number of borrower households

( $p < 0.001$ ). Welch's F test [ $F(4, 14809.27) = 9295.20$ ,  $p < 0.001$ ] confirmed that there was a difference in the interest rates between major lender groups. Hence, the hypothesis H8 was also proved to be true. The data were normally distributed due to the central limit theorem ( $N=44,745$ ) (Ghasemi & Zahediasl, 2012). A Games Howell's Post Hoc test revealed that banks ( $M=13.77\%$ ,  $SD=2.39$ ) had the lowest interest rates while the interest on loans obtained from other ( $M=25.74\%$ ,  $SD=7.29$ ) informal sources was the highest ( $p < .001$ ). Cooperatives ( $M=17.22\%$ ,  $SD=2.66$ ) provided the second-lowest interest rates compared to neighbor ( $M=24.55\%$ ,  $SD=5.76$ ), relative ( $M=23.16\%$ ,  $SD=7.40$ ), and others (Figure 9). The test revealed that the difference in interest rate between all lender groups was significant ( $p < .001$ ).

The lowest average interest rate was charged by banks followed by cooperatives. It was found that the informal sources like neighbors, relatives, and other

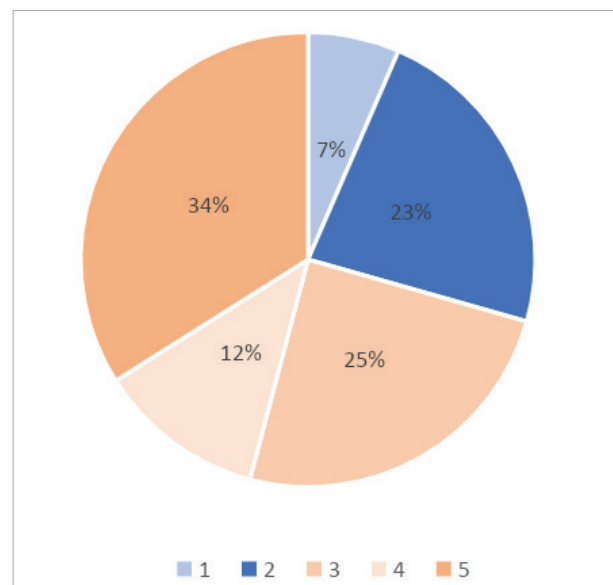


Figure 10. Percentage of lenders

sources charged higher interest rates than formal sources. The result suggested that because of the long process of acquiring a loan from banks and co-operatives and collateral management issues, people sought loans from informal sources despite the higher interest rates. The informal sources were major lenders and also charged the highest interest rates. Therefore, since a large number had borrowed from sources the debt situation of the borrowing households could worsen. This situation could also complicate their livelihood recovery and force them to seek more loans putting them in a vicious cycle of debt (CFP, 2018).

### Interest rates and caste/ethnicity

Again, the Games Howell's post hoc test was performed, with average interest paid by different caste/ethnic groups, as the Levene's F test revealed that the homogeneity of variance assumption was not met ( $p < 0.001$ ). The Welch's F test,  $F(4, 9417.22) = 356.56$ ,  $p < 0.001$ , had reported a similar result. This proved

H9, indicating that there was a difference in the interest rate paid by different ethnic groups. The data was normally distributed due to the central limit theorem ( $N=44,748$ ) (Ghasemi & Zahediasl, 2012). The ANOVA test revealed that Brahmin-Chhetri ( $M=18.53\%$ ,  $SD=7.87$ ) had paid the lowest interest rates compared to households from the other caste/ethnic groups. On the contrary, Janajati ( $M=21.88\%$ ,  $SD=9.52$ ) group had paid the highest interest on loans with significant  $p < .001$ . Finally, Dalits ( $M=20.15\%$ ,  $SD=8.27$ ) group had paid higher interest rates compared to the Newar-Thakali ( $M=19.95\%$ ,  $SD=7.47$ ) and others ( $M=19.31\%$ ,  $SD=5.16$ ) groups. However, the result was significant only for others ( $p < .001$ ). (Figure 11).

There was substantial difference between average interest rates paid by households of different caste/ethnic groups. Janajati and Dalit groups had the highest interest rates even though their average construction cost and loan amounts were lower compared to the Brahmin-Chhetri and Newar-Thakali groups. This could have been related to the investment capacity.

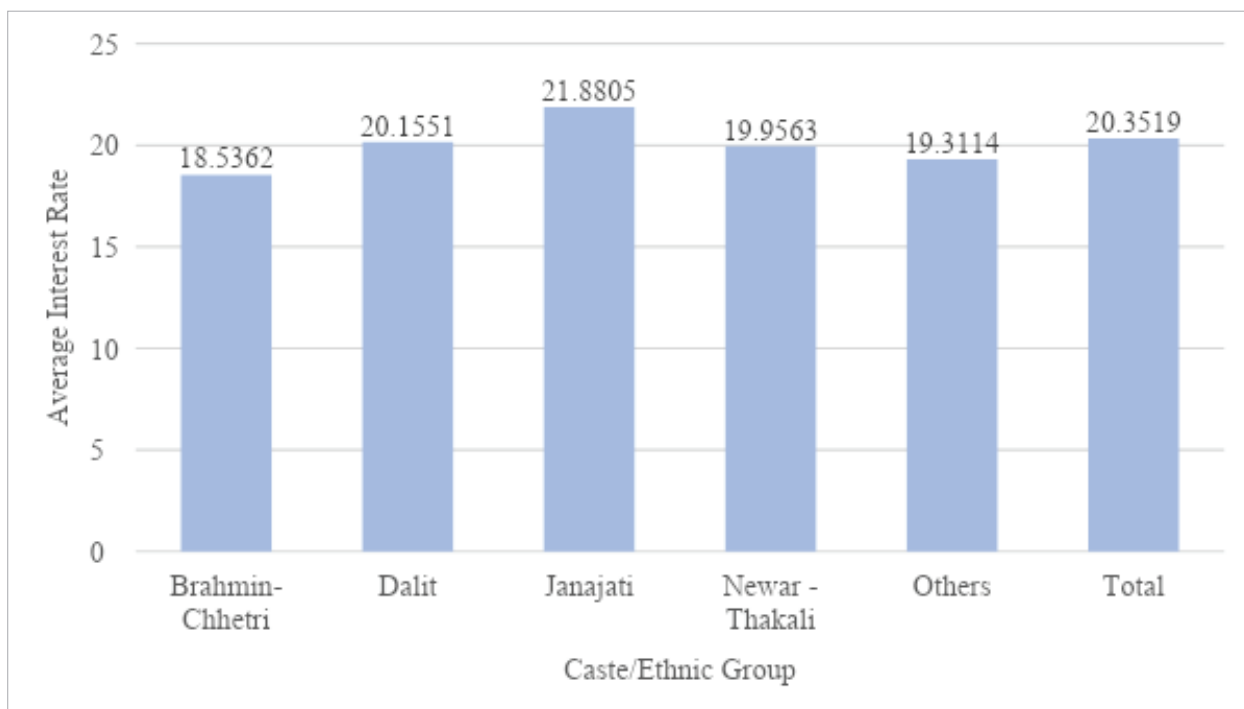


Figure 11. Average Interest rate paid by different caste/ethnic groups

The lower investment capacity of Dalit and Janajati groups meant that they had lower access to formal loans and had to rely on informal sources. This had forced them to pay higher interest rates. The problem of accessibility for socially and economically deprived groups was also clear in the case of access to finances (The Asia Foundation, 2016).

### Interest rate and gender

The interest rates paid by a male borrower were higher than interest rates paid by a female borrower as revealed by a one way ANOVA test [ $F(1, 48059) = 26.95, p < 0.001$ ]. The test was carried out after confirming Levene's homogeneity of variance F test ( $p = .137$ ) and the distribution of interest rates was normal due to the central limit theorem for large samples ( $N = 48061$ ). The test also proved  $H_{10}$  to be correct. There was a difference between the average interest rates paid by male-headed households and female-headed households, and the result showed that male-headed households tended to pay higher interest rates compared to female-headed households.

### Conclusions and recommendations

This study had set out to examine the cost of the reconstructed house and its financial management in two earthquake-affected districts of Nepal. The research has confirmed that the average construction cost was more than twice the government grant amount. Therefore, it can be concluded that the government grant was insufficient to complete house construction, with earthquake-resilient features and therefore additional financing was required either from loans or using own money. The additional cost was the financial burden on the households, which had forced them to manage the financial shortfall by seeking a loan from informal sources at a higher interest rate.

There was evidence to suggest that the construction cost differed for different structure types, caste/ethnicity, and gender. There was similar evidence of significant differences in loan obtained for building

different structures, and in terms of lenders, caste/ethnicity, and gender. The result confirmed that interest rates differed in terms of lender, caste/ethnicity, and gender.

The preference of SMM (comparatively lower-cost housing structure type) meant that the households were aware of the lower investment, which was dependent on social stratification (Bennett et al., 2008). The results also suggested that caste/ethnicity influenced the investment made in reconstruction. There was a tendency of households with higher investment capacity seeking more loans. This was either due to higher access to the sources of loan or confidence to pay back the loan.

The research showed that more loans obtained by the household came from the informal sector compared to the formal sector. This was likely to worsen the debt situation of the households. The result showed that the proportion of households seeking loans from informal sources was higher compared to those borrowing from formal sources, while the interest rate paid by the facilitated group like Brahmin-Chhetri and Newar-Thakali was lower. Those borrowing preferred informal sources despite the higher interest rates because of the tedious process of securing a loan from formal sources and also the requirement of collateral. Yadav et al. (1992) had suggested that the collateral valuation of rural land was low, which could have been another reason. It is therefore necessary for the government to understand the importance of supporting low-interest housing loans, and also to strengthen the capacity of Dalit and Janajati groups to pay back the loans, which were obtained at a higher interest rate compared to other social groups.

The owner-driven reconstruction approach, with limited access to resources and the requirement for building earthquake-resilient structures to be eligible for the government grant, pushed the house owners to obtain loans. The additional costs of the construction process left the households with no other option but to borrow money from the range of lenders accessible in rural areas. The housing reconstruction program had required beneficiary households to have bank

accounts but had not considered the need to provide loans through banks and financial institutions.

Future studies, could examine the perspective of the house owners on reasons leading to decisions to borrow at higher interest rates and also on the status of payback, and the capacity of borrowers to repay. Such studies could also explore if these loans were obtained only to complete house reconstruction within the government deadline, and whether or not the government had plans to support house owners to enhance their payback capacities. The impact of the additional financial burden on households resulting from house reconstruction is another area of study.

In summary, a combination of limited access to formal financial institutions, the additional reconstruction cost, and higher interest rates have worsened the exposure of households to debt. Therefore, future owner-driven housing reconstruction programs would need to address the socio-economic stratification of communities in the policies and programs.

## Acknowledgments

We thank the technical assistance team of the EHRP project of the Central Level Project Implementation Unit (CLPIU Building) for data collection. We also thank both CLPIU Building and the EHRP for allowing us to use the data.

All the views presented are of the authors and do not represent the views of CLPIU Building or the EHRP.

## References

- [1] Bennett, L. et al., 2008. Caste, ethnic, and regional identity in Nepal: Further analysis of the 2006 Nepal Demographic and Health Survey. Population Division, Ministry of Health and Population, Government of Nepal.
- [2] Besley, T. J. et al., 2001. Household participation in formal and informal institutions in rural credit markets in developing countries: Evidence from Nepal. Background Paper Prepared for World Development Report 2001/2002, Institutions for Markets.
- [3] Bothara, J. K. et al., 2016. The Challenges of Housing Reconstruction after the April 2015 Gorkha, Nepal Earthquake. Technical Journal of Nepal Engineers' Association, Special Issue on Gorkha Earthquake 2015. XLIII-EC30, 1, 121–134.
- [4] Canagarajah, S., & Sethuraman, S. V. 2001. Social protection and the informal sector in developing countries: Challenges and opportunities. World Bank.
- [5] CBS (ed.), 2014a. Population monograph of Nepal, (Vol. 1). Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics.
- [6] CBS (ed.), 2014b. Population monograph of Nepal, (Vol. 2). Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics.
- [7] CBS (ed.), 2014c. Population monograph of Nepal, (Vol. 3). Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics.
- [8] CEDIM, CATDAT, & Earthquake-Report.com. 2015. Nepal Earthquake-Report No.3.
- [9] CFP, 2018. Community perception report; Reconstruction, Food Security, Livelihood and Protection. Inter-Agency Common Feedback Project, UN.
- [10] Chang, Y. et al., 2010. Resourcing challenges for post-disaster housing reconstruction: A comparative analysis. *Building Research & Information*. 38(3), 247–264. <https://doi.org/10.1080/09613211003693945>.
- [11] Chang, Y. et al., 2012. Changes in resource need for post-disaster reconstruction: A longitudinal study in China. *Building Research & Information*. 40(3), 327–336. <https://doi.org/10.1080/09613218.2012.684867>.
- [12] Cho, S. et al., 2001. Integrating transportation network and regional economic models to estimate the costs of a large urban earthquake. *Journal of Regional Science*. 41(1), 39–65. <https://doi.org/10.1111/0022-4146.00206>.
- [13] Comerio, M. C., 1997. Housing Issues After Disasters. *Journal of Contingencies and Crisis Management*. 5(3), 166–178. <https://doi.org/10.1111/1468-5973.00052>.
- [14] Delaney, P. L., & Shrader, E., 2000. Gender and post-disaster reconstruction: The case of Hurricane Mitch in Honduras and Nicaragua. Decision Review Draft. LCSPG/LAC Gender Team. The World Bank, Washington, DC.



- [15] DUDBC, 2015. Design Catalogue for Reconstruction of Earthquake Resistant Houses, (Vol. 1). Department of Urban Development and Building Construction. Ministry of Urban Development.
- [16] DUDBC, 2017. Design Catalogue for Reconstruction of Earthquake Resistant Houses, (Vol. 2). Department of Urban Development and Building Construction. Ministry of Urban Development.
- [17] Freeman, P. K., 2004. Allocation of post-disaster reconstruction financing to housing. *Building Research & Information*. 32(5), 427–437. <https://doi.org/10.1080/0961321042000221016>.
- [18] Ghasemi, A., & Zahediasl, S., 2012. Normality Tests for Statistical Analysis: A Guide for Non-Statisticians. *International Journal of Endocrinology and Metabolism*. 10(2), 486–489. <https://doi.org/10.5812/ijem.3505>.
- [19] Goda, K. et al., 2015. The 2015 Gorkha Nepal Earthquake: Insights from Earthquake Damage Survey. *Frontiers in Built Environment*, 1. <https://doi.org/10.3389/fbuil.2015.00008>.
- [20] Hoaglin, D. C., & Iglewicz, B., 1987. Fine-Tuning Some Resistant Rules for Outlier Labeling. *Journal of the American Statistical Association*. 82(400), 1147–1149. <https://doi.org/10.1080/01621459.1987.10478551>.
- [21] Hoaglin, D. C. et al., 1986. Performance of Some Resistant Rules for Outlier Labeling. *Journal of the American Statistical Association*. 81(396), 991–999. <https://doi.org/10.1080/01621459.1986.10478363>.
- [22] HRRP, 2017. Cost of Construction. Housing Recovery Reconstruction Platform.
- [23] HRRP, 2019. The Path to Housing Recovery, Nepal Earthquake 2015: Housing Reconstruction. 4, 32. Housing Recovery Reconstruction Platform.
- [24] Jayasuriya, S., & McCawley, P., 2008. Reconstruction after a major disaster: Lessons from the post-tsunami experience in Indonesia, Sri Lanka, and Thailand. ADBI Working Paper.
- [25] LRMP Nepal, 1986. Land resources mapping project. Survey Department, Government of Nepal and Kenting Earth Sciences.
- [26] Lyons, M., 2009. Building back better: The large-scale impact of small-scale approaches to reconstruction. *World Development*. 37(2), 385–398.
- [27] Mainali, J., & Pricope, N.G., 2017. High-resolution spatial assessment of population vulnerability to climate change in Nepal. *Applied Geography*. 82, 66–82. <https://doi.org/10.1016/j.apgeog.2017.03.008>.
- [28] Manandhar, B., 2016. Remittance and earthquake preparedness. *International Journal of Disaster Risk Reduction*. 15, 52–60. <https://doi.org/10.1016/j.ijdr.2015.12.003>.
- [29] Massey, D. S. et al., 2010. Environmental change and out-migration: Evidence from Nepal. *Population and Environment*. 32(2–3), 109–136. <https://doi.org/10.1007/s11111-010-0119-8>.
- [30] NPC, 2015. Nepal Earthquake 2015: Post Disaster Needs Assessment Vol. A: Key Findings. National Planning Commission, Government of Nepal.
- [31] NRA, 2015. Grant Distribution Guideline. National Reconstruction Authority, Government of Nepal.
- [32] NRA, 2017. Private Housing Reconstruction, Technical Inspection Guideline. National Reconstruction Authority, Government of Nepal.
- [33] Paul, B. K. et al., 2017. Effectiveness of earthquakes relief efforts in Nepal: Opinions of the survivors. *Natural Hazards*. 85(2), 1169–1188. <https://doi.org/10.1007/s11069-016-2627-z>.
- [34] Russell, T. E., 2005. The humanitarian relief supply chain: Analysis of the 2004 South East Asia earthquake and tsunami [PhD Thesis, Massachusetts Institute of Technology]. <http://hdl.handle.net/1721.1/33352>.
- [35] Steinberg, F., 2007. Housing reconstruction and rehabilitation in Aceh and Nias, Indonesia—Rebuilding lives. *Habitat International*. 31(1), 150–166. <https://doi.org/10.1016/j.habitatint.2006.11.002>.
- [35] Survey Department, (n.d.). Shapefile (GIS Data) for Political and Administrative Map of Nepal. Retrieved May 27, 2020. <http://dos.gov.np/download/news-events/shapefilegis-data-for-political-and-administrative-map-of-nepal> (accessed 10 September 2020).
- [36] The Asia Foundation, 2016. Nepal Government Distribution of Earthquake Reconstruction Cash Grants for Private Houses. 48.
- [37] Tukel, O. I., & Rom, W. O., 1998. Analysis of the characteristics of projects in diverse industries. *Journal*

- of Operations Management. 16(1), 43–61. [https://doi.org/10.1016/S0272-6963\(97\)00016-8](https://doi.org/10.1016/S0272-6963(97)00016-8).
- [38] Twigg, J., 2006. Technology, post-disaster housing reconstruction and livelihood security. Disaster Studies, Working Paper. 15.
- [39] UNDP, 2019. Building back better in earthquake-prone Nepal. Medium. <https://medium.com/@UNDP/building-back-better-in-earthquake-prone-nepal-a1f5750b2022> (accessed 10 September 2020).
- [40] Yadav, S. et al., 1992. Segmentation in rural financial markets: The case of Nepal. World Development. 20(3), 423–436.



## House, Household and Home: Revisiting Social Science and Policy Frameworks through Post-Earthquake Reconstruction Experiences in Nepal

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*Keywords: private housing, reconstruction, household, kinship, land ownership, ethnography, community-based research.*

### Abstract

Nepal's post-earthquake reconstruction process has raised a series of critical policy questions about how the concepts of "household", "house", and "home" are differentially defined in the context of post-disaster relief, recovery, and reconstruction programs. These definitions, in turn, inform both material outcomes and perceptions of them, with potential long-term effects in both structural and sociocultural terms. We ask: How have the different definitions of 'household', 'house' and 'home' as articulated in policy documents, and implemented in the field, shaped the process of beneficiary identification and its outcomes? How have those definitions have been understood and internalized by affected citizens, and how have they influenced both the material outcomes of reconstruction (what types of structures are built), and citizens' experiences of the process (how homeowners feel about what they have built)? Our study is based on literature reviews, policy document analysis, and extensive ethnographic research conducted in three earthquake-affected districts (Bhaktapur, Dhading, and Sindhupalchowk) between 2017-2020 as part of our collaborative research partnership, 'Expertise, Labor and Mobility in Nepal's Post-Conflict, Post-Disaster Reconstruction' (funded by Canada's Social Science and Humanities Research Council in collaboration with Social Science Baha and the Central Department of Anthropology, Tribhuvan University). Our research shows that both 'household' and 'house' have been deployed as key concepts in different ways in the post-earthquake reconstruction process, with some ambiguity about the relationship between the two. This has led to a range of structural and sociocultural outcomes, which vary in each community. Yet neither 'household' nor 'house' alone captures the full affective meaning of 'home' as experienced by people living through the process of reconstruction. Our paper brings their voices into conversation with the policy domain.

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## 1. Introduction

### 1.1 Overview

The reconstruction process in the wake of Nepal's 2015 earthquakes has raised a series of critical questions about how the concepts of "household", "house", and "home" are differentially defined and used in contemporary Nepal, both by policymakers and community members. From the first days of immediate post-earthquake relief, through subsequent phases of recovery and reconstruction, both government and NGO-implemented policies towards Nepal's earthquake-affected citizens have vacillated between a focus on "the household" and "the house" as the meaningful unit for the allocation of aid to the nearly 1 million families ultimately determined to have lost their primary residence. Yet neither of these concepts alone captures the full affective meaning of "home" as experienced by people living through the process of reconstruction. Our paper seeks to understand how these categories were differentially defined in policy documents; how their implementation affected community members' engagement with the formal reconstruction process; and ultimately how these definitions affected the material and social outcomes of reconstruction.

Immediately after the 2015 earthquakes, relief was distributed at the local level on an ad hoc basis. The decisions were influenced by pre-existing economic and kinship-based definitions of 'the household' from the Nepal Census, Living Standards Survey, and various other surveys and development initiatives. However, the post-earthquake national reconstruction program focused on the physical unit of "the house" and its linkage to land ownership as a prerequisite for reconstruction grants. Full recovery in the sense implicit in both the concepts of 'owner driven reconstruction' and 'build back better' might be understood as achieving a holistic sense of belonging in the transformed post-disaster environment that 'home' conveys. Our data shows that in most cases, this has not yet been achieved in Nepal.

We argue that this outcome can be attributed to three

main factors: (1) inconsistent and ad hoc criteria for defining 'house' and 'household' in policy documents that did not adequately engage with lived realities in Nepal and the wealth of existing social scientific literature about them; (2) poor communication about the criteria that did exist; and (3) the over-reliance on antiquated notions of citizenship, which relied on evidence of land ownership as the primary indicator of eligibility for enrolment in the reconstruction program, and therefore as the only legitimate basis from which to make claims on the state. In order to secure their claim to ownership and build their future living spaces, citizens had to negotiate a complex web of relationships with multiple levels of the state—many of which are also in a fluid process of restructuring—as well as a wide range of I/NGOs and private corporate interests. The objective is to prove themselves to be affected citizens worthy of resource investment. These negotiations between citizens, the state, the built environment, and the landscape take place within a context of high mobility, which also complicates the presumed isomorphic relationships between "household", "house" and "home", instead creating a nested set of overlapping networks and structures.

Much recent scholarship has highlighted the critical role that migration for labor and education plays in Nepal's contemporary political economy and sociality (Childs and Choedup 2018, Sijapati and Limbu 2017). In the face of such mobility, our data shows that houses become important anchors for disaggregated household-based livelihood strategies when many members may not reside in the physical house itself, yet its existence remains central to their own ability to travel away from it. Attention to mobility reveals how reconstruction policies based upon sedentary conceptualizations of the structural form of the "house" and the social form of the "household" as coterminous and fixed in place may miss critical dimensions of these categories at the experiential level.

Ultimately, we argue that the experience of post-earthquake reconstruction in Nepal has highlighted conceptual difficulties with the existing legal definitions of ownership and residence, and challenged



people's sense of belonging at the affective level. This is an ironic outcome for a program that was promoted as an "owner-driven" model of reconstruction, pushing us to think further about how the definition of "ownership"—and the material and social units in relation to which it is defined—matter for both social science analysis and policy outcomes.

## 1.2. Conceptual framework of the study

By working with a tripartite schema of house, household, and home, we draw from and expand upon existing social scientific literature that has proposed various bipartite distinctions between house and home. Classical anthropological approaches to the "house" have often treated it as either a metaphor for kinship (Bourdieu 1990; Lévi-Strauss 1982 [1979]) or as a container for the socialities and material cultures that live within its walls (Miller 2001), rather than as a site for anthropological analysis in its own material form.

In some previous literature, authors have attempted to distinguish between houses as units of sociality versus units of materiality through, for example, the "social house" versus the "architectural house" (Vellinga 2007); or distinguished between houses as social institutions (often conflated with the "household") and homes as units of belonging in a broad subjective sense (Samanani and Lenhard 2019). There is potential for a rich comparison with the anthropology of Southeast Asian houses, which has previously highlighted the interrelation between materiality and kinship (Carsten 2018; Sparkes and Howell 2003), which as in Nepal has important links to concerns over inheritance (Kunreuther 2009). This has also proven to be true for some of the families in our field sites.

Earlier Himalayan anthropology primarily renders "the house" as an ecological interface between so-called "man" and his environment (Toffin 2016 [1991]). For example, John Gray (2006) suggests that houses substitute for the natural world in the tantric Hindu cosmology of Kholagaun Chhetris. Similarly, Fricke describes how, "an ideal Tamang home exists

in people's minds", yet he also recognizes that, "only a few approach this ideal" (Fricke 1993 [1986]:38).

We build upon these approaches in recognizing the central role that houses play in shaping identity in Nepal, but depart from them in three key ways. First of all, we suggest that houses interact with processes of individual and collective self-conception in a processual and fluid manner, in addition to acting as important points of fixity in what are often disaggregated and mobile livelihood schemes. In this we expand upon Sarah Besky's (2017) analysis of the house as a site of fixity in Darjeeling by suggesting that it is not a matter of fluidity in opposition to fixity, but both at once — perhaps in variegated ways for different families and individuals.

Second of all, we demonstrate how houses mediate not only between people and their environment, but between people and their systems of governance. In our ethnography of post-earthquake residential reconstruction, a consideration of "the house" as a material structure in relation to "the household" as a social structure reveals a complex understanding of the modes of ownership and belonging that constitute "the home". These are mutually comprised of a shifting set of relationships between territory, built forms, families, individuals, and multiple layers of the state, as well as other agents of governance such as I/NGOs. Such an approach complements more recent scholarship that identifies "the house" as a site of middle-class aspiration and real estate speculation in Nepal (Nelson 2017, Haxby 2017) as well as rights claims by the landless poor (Ninglekhu 2017) in the country's urban centers.

Third, we link our consideration of these issues in Nepal to global literature on post-disaster housing reconstruction (Barrios 2014; Cernea 1997; Duyne Barenstein 2016), where questions about what comprises a "house" and a "household" are linked to the UN Human Rights Council framework that recognizes adequate housing as a basic human right. For instance, in her analysis of post-tsunami reconstruction in Tamil Nadu, India, Jennifer Duyne Barenstein explains:

*Questions arose such as what does 'all affected people' mean? How does such a promise account for different degrees of disaster impacts? Should each household get a house? How should a household be defined? Does it make sense to give the same housing support to a small nuclear and large extended family? If a young couple lived with their elderly parents, who should get a house? Such questions were not, however, addressed in formulating reconstruction policy. (2016: 255).*

The fact that the same questions were asked in Nepal more than 10 years later indicates that there is still a pressing need for these definitional issues to be addressed pre-emptively as part of global disaster risk reduction, recovery, and reconstruction best practices.

## 2. Methodology

### 2.1 Research framework

Our research was funded by a Partnership Development Grant from Canada's Social Science Research Council, "Expertise, Labour and Mobility in Nepal's Post-Conflict, Post-Disaster Reconstruction: Construction, Finance and Law as Domains of Social Transformation". The partnership includes colleagues with backgrounds in anthropology, art history, community and regional planning, development studies, economics, educational studies, engineering, geography, law, political science, policy studies, and religious studies.

The research team began with a review of relevant policy documents, media, and scholarly literature from anthropology, geography and other social science fields, and then conducted ethnographic fieldwork in three sites. The earthquake-affected districts of Bhaktapur, Dhading and Sindhupalchowk were selected for the study because they together demonstrated important variations, including in terms of demography, geography, economy, rural-urban dynamics, and proximity to state presence, which influenced the housing reconstruction process in each site differently.

Bhaktapur Municipality offers a view into the

challenges of urban housing reconstruction as well as the reconstruction of major heritage sites. The village of Borang located in the northern part of Dhading district was chosen as a rural counterpart to Bhaktapur in terms of housing reconstruction, and, second, because it was a site of the technical assistance program, Baliyo Ghar, implemented by the National Society for Earthquake Technology–Nepal (NSET–Nepal), a Nepali non-governmental agency working on issues of seismic preparedness and, since the 2015 earthquakes, reconstruction. In Sindhupalchowk, the research site was Kartike Bazaar and the adjoining villages of Manje and Golche. Kartike is a small market town with road access amidst an otherwise rural area, and was chosen to understand the dynamics in a setting where the Baliyo Ghar program was not being implemented.

The 2011 census shows wide caste and ethnic variation in each of our study districts as a whole, however our specific field sites within these districts were more homogeneous: the population of the core heritage area of Bhaktapur Municipality consisted mostly of Newars; the residents of Borang village in Dhading were primarily Tamangs, along with a numerically small Dalit population; and Kartike Bazaar in Sindhupalchowk was inhabited by a mix of Newars and Tamangs, along with a few Brahmin and Chhetri families. All interviews were conducted in Nepali and translated into English by team members for presentation and publication.

Research was conducted in three phases. In the first phase, from March to May 2018, the team primarily conducted interviews with individuals at the household level. In the second phase, from September 2018 to January 2019, the focus was on key local institutions and individuals, as well as government agencies and other relevant organizations. A third phase focused on national level organizations based in Kathmandu took place from mid-2019 through early 2020, and also included a research visit to Dhading district. The research team conducted formal and informal interviews with over 180 individuals across three districts, both male and female.

Data was coded and analyzed according to thematic

keywords. Throughout the research process, diverse members of the partnership team provided input on research design and contributed to analysis.

## 2.2 Limitations

As a collaborative research partnership, our work departed from the model of “traditional” ethnography, which is based on a lone researcher’s individual experience. Instead, we worked in a team structure, which means that data in this paper was contributed by multiple individuals. It therefore does not present “thick description” from a single author’s perspective, or focus only on one site. Rather, it presents a wide range of complementary material from three different field sites to provide a comparative perspective on experiences of the reconstruction process in relation to the policy documents that guided it.

Further, we do not limit our analysis to a specific ethnic community, nor focus on the culturally distinctive elements of ‘house’ and ‘household’ definitions. Rather, we look at how nationwide policy instruments sought to define these categories, and how they were subsequently experienced by a wide range of earthquake-affected people.

Finally, for the purposes of this paper we do not take a gendered approach. We have identified interlocutors as male or female in most cases, but we did not set out to systematically examine the impact of gender on reconstruction experiences, so that is not a focus of our analysis.

## 3. Results

### 3.1 Defining “the household”

According to the Nepal Living Standard Survey 2010/11, the Central Bureau of Statistics has adopted the definition of “household” based on the United Nations guidelines stated in “Principles and Recommendations for Population and Housing Censuses, Rev 2” (UN, 2008). These guidelines define a “household” as, “arrangements made by persons, individually or in

groups, for providing themselves with food or other essentials for living” (CBS 2011). A household may consist of one or more persons who may be related or unrelated, and may have a common budget. The same definition of household is employed in the Population Monograph of Nepal 2014, Annual Household Survey 2014/15 and Nepal Labor Force Survey 2008. The latter further clarifies that two factors must be present to produce a household: dwelling under one roof and eating together. Neither one on its own is sufficient: “People who live in the same dwelling, but do not share food expenses or eat meals together, are not members of the same household ...Likewise, people who eat together but do not live in the same dwelling are not members of the same household.” (CBS 2009). The 2003 Population Monograph further informs us that, “This definition of household has been used in population census of the country since 1952/54” (CBS 2003).

This long-operative definition of the household based on separated kitchen or cooking space matches with Nepali conceptualizations of the household in lived experience, as expressed in the term *chulo*, which literally means “hearth”. Roughly synonymous to *chulo* is the term *bhancha* which refers to kitchen. The phrases “*chulo*” or “*bhancha chuteko*” (separate kitchens) were commonly used across all of our field sites to designate a separate household unit in practice: a group of people, related or unrelated, who both dwell and eat together. However, our interlocutors also understood that not all *chulo* are *gharduri*, the formal term for a legally registered “household”. These differences significantly affected flows of post-disaster resources.

The very first relief payments of NRs. 100,000 (US\$ 892.22) were provided to the households who lost a family member in the earthquake, followed by NRs. 30,000 for funeral rites. Then, cash grants of NRs. 15,000 for temporary shelters and NRs. 10,000 for winterization relief were provided to “earthquake-victims” identified in the initial damage assessments with, priority given to “red-card” holders with “fully damaged” houses (TAF, 2016). Later, an NRA-led CBS survey reassessed damaged houses to identify beneficiaries for private housing reconstruction grants of

NRs. 300,000 and retrofitting grants of NRs. 100,000. Soon thereafter ideas of the “household” came into play when “beneficiary cards” were issued to a single ghar muli (household head) for the entire beneficiary family. The 2015 Post Disaster Needs Assessment did not offer a clear definition of household, stating only: “The total number of houses to be reconstructed has been calculated on the basis of number of households made homeless” (NPC 2015). This quotation indicates a lack of terminological clarity, as it does not clarify what the relationship between the ‘households made homeless’ and the “total number of houses” is.

These definitional ambiguities became challenges in lived reality for many of the participants in our research. For instance, in Bhaktapur, we documented multiple household units—or chulo—living in the same house, understood in terms of the physical structure of the building. Usually, these household units comprised of multiple brothers living together with their families in different floors/apartments or rooms of their father or grandfather’s house. Many of these families were separated and cooked in separate kitchens. If we abide by the legal definitions above, these latter kinds of families should be considered as separate households despite living under the same roof. However, the separate ownership of these families over the house property was not recognized as legally registered individual gharduri in many cases. This was because many people had not transferred ownership from their fathers or grandfathers into the current generation’s names, a process which would have enabled recognition of the multiple chulo, converting each of these to gharduri. In some of these families, property had not been partitioned for two generations or more. Some participants had joint-ownership certificates with their brothers over one house property, and in some cases, property ownership was legally recorded in the name of one brother or an uncle also.

### 3.2 Defining “the house”

Meanwhile, Nepal’s Central Bureau of Statistics (CBS) defines “house ownership” as the legal status of owning

a house or part of a house or apartment that usually is used by the household (Kayastha and Shrestha 2003). Yet it’s made clear that, “There is no standard definition of residential house, ownership of house and its type in the country,” and that, “this causes problems in comparing data obtained from different sources” (Kayastha and Shrestha 2003: 175). Minimally, a “house refers to a structure where household is using it as a shelter and which is closed or surrounded by walls or curtains made of many types of materials such as mud, wood planks, bricks, stone, concrete, etc. A house may contain any number of rooms, but it must have a separate way to get inside. It is noted here that a house may have contained more than one household” (Kayastha and Shrestha 2003: 175). Hence, the concept of a “house” as a physical unit was never equivalent to a “household” that was conventionally defined based on family or kinship arrangements. However, these concepts were awkwardly tied through post-disaster reconstruction policies.

The first major step in the reconstruction process was identifying earthquake affected beneficiaries who qualified for housing grants of up to NRs. 300,000. These grants were to be distributed in three “tranches”, with the first tranche issued after verification of ownership, and the subsequent two issued after approval by an NRA engineer that the houses were reconstructed according to earthquake resilient building codes. Despite, or perhaps because of, the well-known issues with these definitions, the NRA issued vague guidelines at the central level that confused beneficiaries, as well as its line agencies responsible for managing the process of grant access (TAF 2016). The beneficiary selection guidelines were first introduced in the NRA’s *Private Housing Reconstruction Grant Distribution Procedure, 2072*, which was reissued in the 2073 version, which was significantly amended again in 2074 and 2075. Until 2073, the beneficiary selection procedure was not based on the separation of cooking space, but rather the pre-earthquake existence of physical structures. The guidelines reiterated the simplistic criteria of “households made homeless” under the assumption that each household would reside in



a separate housing unit. This assumption also translated into the idea that separate housing units stood on separate land parcels owned by separate beneficiaries, whether formally partitioned or not. Hence, questions arose about who owned the land on which the house sat, and who was legally entitled to rebuild each structure.

These questions diverted the focus from the full family unit of the household(s) living in each house to individual members with the legalized status of property ownership. NRA's *Private Housing Reconstruction Grant Distribution Procedure, 2072* stipulated that households needed to have legal certificates of land ownership or *dhanipurja* predating the earthquakes to be eligible for the housing reconstruction grant. Those households who had not partitioned their house property, but had been living separately before the earthquake were also eligible, but conditions were applied. They first needed to confirm their separated status through a public inquiry, partition their share of land, and gain legal ownership certificates for it (NRA 2015). Such criteria that relied upon the legal criteria of land ownership to define house-ownership made grant access difficult for many people whose houses had been destroyed. No legal distinction was made between house ownership and land ownership: in other words, even if a family had built their own house with their own resources by mutual agreement on land formally registered to someone else, there was no straightforward way for them to claim ownership over the house for the purposes of reconstruction without also partitioning the land.

The later amendments improved and elaborated these policies to make beneficiary selection more flexible, and also addressed the issues of relocation, repairs and retrofitting, surveyed lands, grant access, grievance procedures and so on. However, this did not change the fact that beneficiaries still needed to have land ownership certificates to qualify for grants, and have their damaged house acknowledged by the CBS assessment survey (with an individual survey slip number). The idea of a "household" as separated *chulo* was not acknowledged with regards to grant

beneficiary selection until the 2074 amendment. This implied that households living in the same house but with separate kitchens prior to the earthquake could now qualify as separate beneficiaries. However, most of our rural research participants had already received their beneficiary cards between 2016 to early 2017, so the effect of these amendments only played out for those few participants whose eligibility was confirmed through grievance surveys. The amendment also stipulated that each selected beneficiary would need to partition their land and then build a separate house, whether or not they lived separately or together before the earthquake.

Reconstruction guidelines therefore reified the notion of *gharduri* as the only legally recognizable form of "household" by linking it in a one-on-one manner to an individual physical unit of the "house", and further to the land on which it sat. Some donor organizations promoted this strategy, believing that restricting eligibility to a clearly defined *gharduri* would enhance accountability, as well as creating a natural cap on the number of eligible households—both strategies to limit and protect their financial exposure.

The resulting guidelines therefore had difficulty accommodating the ground reality of multiple household units that were living together in one house—as was common in urban areas such as Bhaktapur—or conversely, as was often the case in rural areas such as Dhading and Sindhupalchowk, single households spread across multiple housing units. In the case of compact urban settlements like Bhaktapur, people were at a disadvantage because multiple households were living under one roof, but they were not eligible for separate reconstruction grants. The amendments after 2074 allowed these separate households living under one roof to qualify as different grant beneficiaries, but it also entailed that each grant beneficiaries would need to build a separate house, which was still troublesome for multiple homeowners that wished to pool their grants to rebuild one house, as before. By contrast, in rural areas such as Sindhupalchowk and Dhading, multiple family members were able to apply for the grants by showing that they were living separately in

different houses before the earthquake—but only when their land title deeds matched their actual pattern of residence, which was often not the case.

A different definition of households as taxable units can be found in the *House and Land Revenue Tax Act 2019* (NLC 1962). The taxation criterion distinguishes individuals owning different floors or parts of the same house as separate taxable units. At the same time, it clarifies that even if an individual owner has multiple houses in different areas, it is considered as one taxable unit. If similar criteria were applied to define households in terms of reconstruction, it may have captured both the situation of multiple households living under one roof in Bhaktapur, as well as the situation of one household owning multiple houses units in rural Dhading and Sindupalchowk.

However, the definitions of “household” and “house” actually deployed in reconstruction have created a range of complications for citizens. Further, these definitions have in many cases led to restructuring of kinship relations, as our subsequent ethnography shows.

### 3.3 How to be a “household”

In Bhaktapur, it was difficult to come to a consensus, as there were rampant family conflicts over the ownership of tiny plots of land. Even for joint-grant access, people needed to obtain ownership documents by transferring the house property from the previous to successive generations.

Moreover, households with joint ownership were eligible for only one grant, and all parties had to proceed through the documentation process jointly. If even one householder backed out then everyone else would be ineligible for the grant. A man in Bhaktapur expressed his frustrations with this process:

*I told him (my younger brother) that if we can come to an agreement with each other, we can get NRs.. 150,000 in the second tranche by showing the house design map of my new house. Out of that, I told him that I'd give 50,000 rupees to mother, 50,000*

*to him and keep 50,000 for myself. Otherwise, if he wanted to make a house with that money, then we would make whatever kind of house we can afford with the money. If it is not enough, we can add a little more money for it. But he has not replied. Without his consent, we cannot take out the money...*  
- (P1\_InachoBhaktapur\_2018-03-15\_BL)

*Another Bhaktapur resident concurred, “Now, every brother owns a right over the house. The house is also very small, how do we divide it? Such problems exist among 60-70 percent households here. That’s why it is difficult to come to an agreement.”*- (P2\_Bhaktapur\_2018-03-16\_BL)

Although most common among brothers, such issues also occurred between unrelated households inhabiting the same physical structure. For example, one co-author spoke with a man in Golmadhi, Bhaktapur, who said that he was having a problem as a second-floor homeowner because those who owned the first floor did not want to build due to lack of resources (P3\_Bhaktapur\_2018-03-16\_BL).

In rural contexts, people struggled with the converse problem, where one household was in many cases already spread across multiple houses or small goth (shed) before the earthquakes. This situation was evident in Sindupalchowk. According to the 2011 census, Pangtang had 487 households while Golche had 731. After the earthquake, about 777 households were identified as grant beneficiaries in Pangtang and 985 households identified in Golche. The difference in these numbers is largely made up of households who were already separated into more than one chulo at the time of earthquake, but as in the Bhaktapur cases described, had not updated their land ownership papers. Before the earthquake, many families did not perceive it as necessary to transfer land ownership in order to legitimize additional physical structures built by different family members on their property. Indeed, it was considered unfilial to seek a share in the family property or partition if older generations were still alive. After the older generation’s death,

many families preferred to simply continue with their existing practices rather than formally transferring land title, due to the bureaucratic complexities and costs involved in doing so. At the level of practice, there was a clear distinction between “house ownership” and “land ownership”, but this was not reflected in the legal realities citizens encountered after the disaster.

In order for a familial unit who had separated from their parent’s or grandparent’s family to formally transition from *chulo* to *gharduri*, enabling that unit to receive its own earthquake-affected identity card, a public inquiry, or *sarjiman*, was required. Before the 2017 election of new local governments, this process was handled by the VDC, and afterwards by the newly elected ward officials within the municipality or rural municipality. An application had to be filed in person at the VDC level, and reviewed at the DDC level, with seven witnesses who themselves possessed a *gharduri* card in the same Ward supporting the claim. Any one witness could only confirm two people. All this was to ensure that the immediate community members confirmed that this particular residential unit deserves to be recognized as a *gharduri* on its own terms, and to prevent absentee householders from commandeering resources.

However, in many cases political party affiliation played a role in this process: in our Sindhupalchowk field site, a ward chairperson who was recently elected in 2017 elections, and two NRA field engineers who had come to inspect the houses for the third tranche recommendation, told us that multiple family members of the same household were able to secure beneficiary cards due to their connections to the ruling party.

The rise in household numbers was critiqued in the Nepali press at the time as well as by donors as relief transitioned into a formal reconstruction program (see for example Parajuli 2016). But the ethnographic details we present here suggest a community critique that echoes long-standing scholarly critiques of the neo-classical “household” model (Kabeer 1991) – as community members self-consciously sought to define what a “household” should be in administrative terms

for the purposes of securing resources. By reconstituting kinship relations and the residential patterns with which they were linked, community members found a way to shape their experience as recipients of humanitarian aid. Such strategic action seems to have led to charges of “false victims”, which members of this project have argued elsewhere is a term that does not adequately recognize people’s experiences of hardship (Limbu et al 2019b). While acknowledging that such actions are intended to receive maximum benefit from existing regulatory systems, we can also see how they are a means for actors to express agency and protest the limitations of the system as they experience it.

### 3.4 Producing a “house”

Having secured reconstruction grants, families then struggled with how to build a physical structure in keeping with the approved building codes with numerous designs for “earthquake resistant building”. We now consider the material challenges of producing the physical structure of a “house” in a manner that complies with regulatory requirements, a process through which relationships between citizens and a wide range of government agencies come into view.

The Department of Urban Development and Building Construction (DUDBC) published a building catalogue focusing on rural housing reconstruction in October 2015, which was subsequently adopted by the NRA. Four main types of rural house designs were promoted: stone and mud mortar masonry, brick and mud mortar masonry, stone and cement mortar masonry, and brick and cement mortar masonry. Volume II of the catalogue was published only in March 2017 with 17 house designs to support both rural and urban reconstruction. Meanwhile, urban reconstruction remained in limbo. People in rural areas also faced problems since the house designs and materials were not in line with their needs and available resources. According to the project director of CLPIU at DUDBC, the second volume added additional house designs considering alternative construction materials and people’s cultural needs. Later, in mid-2017, the NRA also published a Corrections/

Exception Manual for Masonry Structures and Repair and Retrofitting Manual for Masonry Structures, which addressed many problems of non-compliance, enabling additional houses to qualify for further housing grants. However, even after revised house designs for urban reconstruction were introduced, the reconstruction process in Bhaktapur did not speed up (cf. Suji et al. 2020).

In Bhaktapur, people needed to follow both the government's building codes for earthquake resistant homes and a second set of 'cultural codes' promulgated by the municipality and the Department of Archaeology. The "Physical Infrastructure and Construction Standard related Regulation, 2060" stipulated house design criteria that required houses within the heritage area of Bhaktapur to maintain the appearance of traditional Newari designs. Many people found this to be "impractical", especially the criteria for jhingati tile roof with 25-30-degree slope and building height limitations of 35 feet (28 feet if a heritage monument was nearby). People said that any house that did not abide by these codes would not get the Ghar Nirman Sampanna Pramanpatra (House Construction Completion Certificate). Without this, the house could not be used as an asset for banking or real estate transactions.

As one Bhaktapur resident explained:

*Nobody can make the kind of house that they (government officials) want. They tell us to make our house in such and such structure with such type of roof. How can we do that? On top of it, the price of materials is increasing everyday—people may or may not have that kind of money. Some people only have ½ ana land or less, if they have to leave half of the land to follow the guidelines, then where would they make the house? (P4\_Bhaktapur\_2018-03-12\_BL)*

Another interlocutor shared details about the tension between ideas of 'traditional' lifestyles and modern realities as embodied in the material design of the house:

*[According to the 'cultural codes']... the height should be 35 feet for a three and half storied building, with a traditional style slope roof. But if we make the sloped roof, we will not have a place to put the water tank ... To follow the standard, our lifestyles should be like in the past. Now, our daily life is not possible without a water tank on the roof which supplies the water for toilet, bathroom, and kitchen. In the past, it was not needed because there was a public water tap ... But now life is not like in the past. Every household uses water from the water tank and that is placed on the top of the roof. Although we are living in the heritage site areas, it is difficult to live our life as in the past. The standards set by the Department of Archaeology and the Municipality have been obstructing the reconstruction process. The engineers should also design houses with complete space for a water tank, or they have to build a cemented water tank which is adjustable with the traditional slope roof. That would help us to meet our needs and the government standards at the same time. (P5\_Bhaktapur\_2018-03-19\_MS)*

In response to these issues, the Mayor of Bhaktapur Municipality acknowledged in an interview that people's economic burdens were increased by the requirements to comply with cultural codes, but also expressed that if people prioritized the practical housing needs over traditional housing designs, they would lose their cultural identity in the long run. To ease financial strain, the municipality also provided various tax reductions and subsidies on construction materials (32% on bricks and jhingati tiles, and 50% on wood). Despite this, many people continued to violate the criteria, especially with regards to *jhingati* roofing, which disqualified them from these incentives and subjected them to further penalties. As tensions between residents and the municipality remained at an impasse, the newly reconstructed houses seemed to be losing the traditional touches of a Newari house, and the municipality ran out of ways to enforce compliance. The mayor told us:



*We have given them every kind of discount that the municipality can afford in the taxes, construction materials and many more to build traditional houses. What more can we do?*  
—(KI8\_Bhaktapur\_2018-09-30\_PCS\_BL)

In Dhading, we encountered a different set of issues. Soon after the earthquake, state presence was at a minimum due to the difficult terrain, so people did not expect much support from the government. Despite the absence of government intervention, the disaster had already taught people that they needed to make their houses stronger for the future. The most ingrained lesson in people's minds was that the upper floor should not be heavy, as it posed a risk of collapsing on them during the earthquake. Hence, people rejected their traditional style of stone houses and instead proceeded to rebuild their own houses, using lighter materials like wood and corrugated galvanized iron (CGI) sheets to rebuild their upper floors.

People invested great time, effort and money to rebuild and repair their old houses. The cost was reported at NRs. 400,000 to 500,000, with some participants even reporting up to NRs. 900,000 because of the increased cost of construction materials and transportation. Nevertheless, people were willing to spend money as they felt ownership and belonging in these houses. Foreign remittances also helped to finance these costs. However, there were also poor households who could not afford to make such structural changes and only made minor repairs. This was long before the reconstruction program was rolled out.

These houses that people had built on their own initiative were mostly of two stories with an additional attic space below the roof. They had enough space to accommodate household members and their guests and store firewood, agriculture equipment, and crops. These homeowners quickly rebuilt their houses in whatever ways they felt were earthquake resilient before the NRA program reached them. When the house design maps prescribed by the government entered Northern Dhading through the National Society for Earthquake Technology (NSET) *Baliyo*

*Ghar* (Strong House) program in late 2016, about 1.5 years after the earthquakes, another phase of reconstruction began.

Many people were initially against building the houses in the style recommended by *Baliyo Ghar*. An NSET official working in the rural municipality described the initial response that he faced:

*At first, when we came to teach people, they got angry. They said things like, "This is my house, I will make it however I want. It's no business of yours. Your organization gives you your salary, so get going on your way."* (KI1\_Dhading\_2018-04-07\_NR\_MS\_PCS\_BL)

As this quotation demonstrates, technical officers were often perceived as outsiders who were meddling in people's personal affairs, rather than as representatives of the state whose job was to advocate for citizens' interests. The main problem was that most people had repaired and were living in their old houses already. Hence, they felt no immediate need to build an additional house. Moreover, within the NRs. 3-lakh budget envelope, it was very difficult for people to build more than a one-roomed house compliant with the building codes. However, as people began to understand what was on offer, attitudes began to shift. Participants described how their motivation increased after they understood that building a separate one-roomed house would provide access to funds.

Further, there were a range of rumors about the consequences of not enrolling in the house reconstruction program, or failing to complete reconstruction, which scared people into compliance. These included rumors that the first tranche might need to be returned; that land ownership certificates would be seized; and that children might be barred from receiving birth certificates and citizenship documents.

Amidst these rumors, some people also believed that the new government-designed houses might actually be a stronger alternative to the previous houses. Although they might not withstand big earthquakes, at least they might have enough time to flee.

We can therefore see that many of the challenges in the reconstruction process have been due to unclear definitions of households, which led to faulty assessments, as well as lack of clear and timely communication about building codes and reconstruction policies. As one DLPIU official in Sindhupalchowk stated, “It is all due to the mistakes of the past that we are facing the current challenges.”

Nonetheless, prodded with rumors, incentives and some hopes of better resilience, Dhading residents began to build houses as per the government standards—often in addition to their already repaired previously standing house. This led to the rise of “one-roomed houses” in the NSET program area, based upon the one-roomed stone-masonry design included among the 17 design models catalogue by the DUDBC and NRA. These one-roomed houses complied with the regulations and were affordable within the grant amount, as they required less labor and materials compared to bigger house designs. Building these houses cost about NRs. 1 to 2.5 lakhs or more (depending on the stones and wood resources that people owned). After reconstruction expenses, people were usually left with some profits. Some interviewees admitted that they were building the one-roomed houses just to access the grant money.

The reconstruction program reached our Sindhupalchowk field site earlier due to its relative proximity to roads, so people had not yet rebuilt old homes in the same way as in Dhading. Their relatively quick enrolment in the reconstruction program led to a different set of challenges, as they built one-roomed houses under the supervision of engineers from various I/NGOs and the NRA. These initial houses were built under the belief that these were the only approved designs—only to learn later that there were advisory alternatives. Along with this misconception, the affordability and efficiency of these houses made them convenient to build for homeowners as well as for involved I/NGOs and the NRA within the given deadlines. These organizations were concerned with demonstrating a visible and quantifiable reconstruction output within their project timelines. In this process, the

ethos of “owner-driven” reconstruction that intended to allow people to rebuild houses according to their own chosen design seems to have lost its essence. Later in Sindhupalchowk, these house designs were corrected and new designs for larger houses of up to two stories were introduced. Even the initially built one-room houses had to be retrofitted at the foundations. This trapped people in a seemingly unending cycle of building and rebuilding, which also led to conflicts between family members about disparate housing outcomes:

*Nowadays, everyone is making two houses. First, they built one. Then, they made another one with DPC [approved foundation technique], so that it would be passed... If the house maps had arrived earlier, we wouldn't have to build two-three houses. It was difficult for us. We had to rebuild again and again. - (P10\_Sindhupalchowk\_2018-05-11\_BL)*

For all of these reasons, people seemed to lack a sense of ownership over these one-roomed houses. They called them *sarkaar ko ghar* (the government's house), or *anudaan ko ghar* (grant house). Both of these terms suggest that the house belongs to an external entity other than its inhabitants.

Like in Dhading, most people in Sindhupalchowk also felt that these houses would be somewhat stronger than the pre-earthquake houses. However, in both sites, people were largely skeptical if they would actually be “earthquake-resistant”:

*Earthquakes destroyed many strong houses; how would this house resist it? However, most people have trust in it. Engineers have brought this design thinking that it is strong. They are also trying, let's see how strong this design will be. - (P12\_Dhading\_2018-04-10\_MS)*

One of the major factors that made the new houses stronger than previous ones was the wooden joints at every two feet interval around the walls. Many participants said that it was the only major difference between the old and new houses. However, people

were especially doubtful about the use of untreated raw wood in these bondages that were liable to rot when it rained. For them, the use of cement and iron rods would have made the houses more resilient, but people did not have the money to buy and transport such construction materials.

Hence, the new houses were widely felt to be inadequate. Most people had plans to modify these houses by adding a floor or extending the porch to make more space in the future, leading to our considerations below about what might make these “grant houses” into “homes”.

#### 4. Discussion: Becoming home?

The distinction between “house” and “home” has been articulated in a range of ethnographic contexts, including in relation to post-disaster reconstruction elsewhere. For example, Robert Barrios notes how in the aftermath of Hurricane Mitch in Honduras, many beneficiaries of government and NGO-sponsored reconstruction, “refused to recognize the structures as homes, repeatedly referring to them as shoebox or matchbox houses” (Barrios 2014: 337). This was due in part to structural faults, but also because the houses were constructed on small parcels of land that, “could not accommodate growing families” (Barrios 2014: 337).

Similarly, in her recent work on tea plantation houses in Darjeeling, Sarah Besky suggests that the difference between the material structure of a “house” and the site of belonging embodied in a “home” lies in the affective labor required to produce the latter through maintenance over time (Besky 2017). Such maintenance includes investment in the physical structure of the building, but this is oriented towards, “turning a house into a fixed space of intergenerational belonging” through making it, “a suitable space for welcoming extended families during festivals” (Besky 2017: 626). It is indeed this long-term work that many earthquake-affected families in Nepal are now embarking upon – and where they see limitations in the houses that they have built through the reconstruction program.

Some of our interlocutors in Sindhupalchowk reflected:

*“The house is okay, but it is very small during the festival and ritual events when relatives visit us. Now, our main problem is we are worried about managing sleeping space when our relatives visit us. We have only one sleeping room and that is only enough for our own family.”* (P13\_Sindhupalchowk\_2018-05-10\_MS)

And in Dhading:

*... people have many belongings such as big bamboo baskets, mats and such, but there is no place to store them... When relatives come, where to make them sleep and where to sleep ourselves? The new house will only be good for a kitchen room. Due to the wooden joints, the house might not collapse and it may be strong, but it is very small.* (P8\_Dhading\_2018-04-08\_MS)

Likewise, a participant referred to living in such situation as *veda bakhra jastaihune*—living like goats and sheep, due to the very small space they now had. (P14\_Sindhupalchowk\_2018-05-11\_BL)

However, through plans to extend the existing one room houses or engage in other forms of maintenance, it is possible that they will eventually become homes. Much remains to be seen, and there is a wide range of opinions about the long-term impacts of the reconstruction experience on identity and belonging. Two members of the same community in Dhading held conflicting views about the long-term prospects of their house becoming home.

An older villager who had retired from the Nepal Army said,

*What sort of cultural identity would this narrow one roomed house reflect? It will instead ruin our culture. People are busy building houses now and they do not know about it, but once the reconstruction is completed then they will realize that this*

*house does not represent the identity of our community.* (P16\_Dhading\_2018-04-09\_PCS)

In contrast, a younger co-villager in his mid-30s who ran a small timber provision and carpentry workshop suggested that,

*I think this house is fine. If I build my house in our traditional style, then maybe in the future our children may not like that house. They may say, 'I do not want to live in this type of house' and may run away from home.* (P17\_Dhading\_2018-04-08\_PCS)

These statements show how ideas of home, modernity and belonging are being negotiated from a wide range of perspectives through the reconstruction process, with meaningful differences across generations. Experiences of mobility play a key role in framing such perspectives; feelings about what makes a house home are shaped by whether individuals actually live under the roof much of the time, or only return to it for festival and other special occasions.

## 5. Conclusions and recommendations: Reflections on ownership and citizenship

To summarize, many people had ambivalent feelings about the reconstruction process during the time of our research. Although people were happy to have some kind of housing, and optimistic about its potential seismic resilience, often the structures were felt to be inadequate for their domestic, familial and cultural needs. This was despite the exhausting and frustrating experience of working to comply with the regulations required to participate in the reconstruction program.

One woman in her mid-30s who had lost her baby daughter in the earthquake summarized her feelings around the constant confusions in the house design maps in this way:

*Yes, we have to be satisfied now, we've made houses three times, I've also become old and weak now.* (P18\_Sindhupalchowk\_2018-05-05\_BL)

These sentiments call into question the extent to which the reconstruction program in Nepal has in fact been “owner-driven”. Rather, although legal land ownership has been the criteria by which eligibility for subsidies has been determined, the constraints within which “owners” have had to produce a “house” recognized as legitimate by the authorities has actually had the effect of weakening their sense of affective ownership.

The insistence on fusing recognition of home ownership with land ownership reflects a very old operating principle of the Nepali state: that legitimate citizenship is based on land ownership. The re-assertion of this principle through the post-earthquake reconstruction program is ironic just at the moment that Nepal was supposed to be completing a process of political transformation, which among other changes, was to put in place new definitions of inclusive citizenship. The material presented in this paper suggests that the process of reconstruction has enabled the state to reassert antiquated notions of land-based citizenship by enrolling citizens in a process that constrains the possibilities for affective ownership by refusing to recognize the distinction between “household” and “house”. This may be in part an unwitting outcome of the donor community’s desire to find an easy pathway to beneficiary “accountability” by limiting eligibility criteria.

Further, we can see how the built form of the house itself—whether in the one-room form found all over rural areas of central Nepal now, or in the multilayered tight urban spaces of Bhaktapur—mediates between family, government, and environment. People’s relationships with their houses are fluid. For some, these reconstruction houses may come to serve as the conceptual anchor for mobile, shape-shifting households understood as a set of kinship relations—but fall short of becoming the day-to-day “home” in which all members of the household actually reside. Yet the material forms that people have built also shape their experiences of ownership, belonging, and citizenship. It remains to be seen what it will take for *sarkar ko ghar* to become home.

The key lessons learned are that government agencies focused on disaster risk reduction—whether from



earthquakes, landslides, floods, storms, or other forms of natural disaster—should put in place clearly defined rubrics for identifying “households” and “houses” *before* disaster strikes. Known relationships between these two entities should be specified in a typological form that aids planners and providers in considering the full range of potential linkages between the social, material, and legal elements of “the home”. These rubrics should be developed through community consultation, with reference to relevant social science literature. They should consider kinship arrangements, common culturally and regionally specific patterns of residence and mobility, actual uses of domestic space, and existing relationships between physical structures for human habitation and ownership of the land upon which they sit.

Of course, no rubric can predict all variations, and flexibility will be required. However, if care and resources are invested in developing adaptable frameworks for beneficiary identification, with community consultation, pilot testing, and verification carried out on a periodic basis before disaster strikes—or between disasters—these frameworks may be implemented in a systematic manner when needed. In the Nepali context, these rubrics should be established in line with the mandates and institutional mechanisms of the new National Disaster Risk Reduction Management Authority (NDRRMA), and further scaled at the federal, provincial, and municipal levels, with the potential for variation at certain levels of the typology in each locality. Finally, information about these and other elements of recovery and reconstruction plans, policies and guidelines, should be communicated early and often (before, during, and after actual disaster) at

the local level in language community members can understand.

Such provisions will help to remove the definitional ambiguities surrounding the concepts of ‘house’ and ‘household’ that remain common in policy frameworks for post-disaster reconstruction in Nepal and beyond. In so doing, we can advance the global objective of ensuring the human right to adequate and appropriate housing for all.

### Acknowledgments

This research was funded by the Social Sciences and Humanities Research Council of Canada (SSHRC) through Partnership Development Grant Number 890-2016-0011, with additional support from Peter Wall Institute for Advanced Studies, Faculty of Arts, School of Public Policy & Global Affairs, and Department of Anthropology at the University of British Columbia (UBC), Canada; Aarhus and Copenhagen Universities in Denmark; and Social Science Baha and its collaborating partner, the Central Department of Anthropology at Tribhuvan University, in Nepal. We are grateful for feedback from participants at the *Epicentre to Aftermath* conference at SOAS University of London in January 2019, where an earlier version of this paper was presented; and from partnership members at two workshops in Kathmandu (2018) and Sandbjerg, Denmark (2019). Bidhyaman Mahatara contributed to the initial research design and implementation and comments from anonymous reviewers strengthened the paper. Most importantly, we thank the community members and officials who shared their experiences.

## References

- [1] Barrios, Robert, 2014. Here, I'm not at ease: Anthropological Perspectives on Resilience. *Disasters*. 38(2), 329-50.
- [2] Besky, Sarah, 2017. Fixity: On the Maintenance of Tea Plantation Houses in Darjeeling, India. *American Ethnologist*. 44(4), 617-631.
- [3] Bourdieu, Pierre, 1990. *The Logic of Practice*. Stanford University Press, Stanford.
- [4] Carsten, Janet, 2018. House-lives as ethnography/biography. *Social Anthropology*. 16(1), 103-116.
- [5] Central Bureau of Statistics (CBS), 2011. Nepal living standards survey 2010-11(Vol. 1). CBS, Kathmandu. <http://cbs.gov.np/nada/index.php/catalog/37>.
- [6] Central Bureau of Statistics (CBS), 2014. Population monograph of Nepal (Vol. 3). CBS, Kathmandu. <http://cbs.gov.np/image/data/Population/Population%20Monograph%20of%20Nepal%202014/Population%20Monograph%20V03.pdf>.
- [7] Central Bureau of Statistics, 2009. Report on the Nepal labour force survey 2008. CBS, Kathmandu. [https://www.ilo.org/wcmsp5/groups/public/@asia/@ro-bangkok/@ilo-kathmandu/documents/publication/wcms\\_118294.pdf](https://www.ilo.org/wcmsp5/groups/public/@asia/@ro-bangkok/@ilo-kathmandu/documents/publication/wcms_118294.pdf).
- [8] Cernea, M., 1997. The risks and reconstruction model for resettling displaced populations. *World Development*. 25(10), 1569-1587.
- [9] Childs, Geoff, & Namgyal Choedup, 2018. From a trickle to a torrent: Education, migration, and social change in a Himalayan valley of Nepal. University of California Press.
- [10] Dwyne Barenstein, J., 2016. The Right to Adequate Housing in Post-Disaster Situations, in: P. Daly & R. Feener (eds.), *Rebuilding Asia Following Natural Disasters: Approaches to Reconstruction in the Asia-Pacific Region*. Cambridge University Press, Cambridge, pp. 236-260. doi:10.1017/CBO9781139683548.010.
- [11] Fricke, Tom, 1993 [1986]. *Himalayan Households: Tamang Demography and Domestic Processes*. Book Faith India, Delhi.
- [12] Gray, John, 2006. *Domestic Mandala: Architecture of Lifeworlds in Nepal*. Ashgate, Aldershot.
- [13] Haxby, Andrew, 2017. Can a Financial Bubble Burst if No One Hears the Pop? Transparency, Debt, and the Control of Price in the Kathmandu Land Market. *Focaal*. 78, 77-89.
- [14] Kabeer, Naila, 1991. *Gender, Production and Well-Being: Rethinking the Household Economy*. Institute of Development Studies Discussion Paper 288. IDS, Sussex.
- [15] Kayastha, R.P. & Shrestha, N.L., 2003. 'Housing and household characteristics and family structure'. *Population Monograph of Nepal*, Vol. 1 (Chapter 5). 173-211. [http://old.cbs.gov.np/population/population\\_monograph\\_nepal\\_2003\\_all](http://old.cbs.gov.np/population/population_monograph_nepal_2003_all).
- [16] Kunreuther, Laura, 2009. Between Love and Property: Voice, sentiment, and subjectivity in the reform of daughter's inheritance in Nepal. *American Ethnologist*. 36(3), 545-562.
- [17] Limbu, Bina et al., 2019a. *Reconstructing Nepal: Post-Earthquake Experiences from Bhaktapur, Dhading and Sindhupalchowk*, Working Paper. Social Science Baha, Kathmandu. <https://soscbaha.org/publication/reconstructing-nepal-post-earthquake-experiences-from-bhaktapur-dhading-and-sindhupalchowk>.
- [18] Limbu, Bina et al., 2019b. *Reconstruction Conundrums*. The Kathmandu Post, February 19. <https://kathmandupost.com/opinion/2019/02/19/reconstruction-conundrums>.
- [19] Ministry of Labour, Employment, and Social Security (MoLESS), 2020. *Nepal Labour Migration Report 2020*. <https://moless.gov.np/wp-content/uploads/2020/03/Migration-Report-2020-English.pdf>.
- [20] National Planning Commission (NPC), 2015. *Nepal earthquake 2015: Post Disaster Needs Assessment, Vol. A: Key Findings*. [https://www.npc.gov.np/images/category/PDNA\\_Volume\\_A.pdf](https://www.npc.gov.np/images/category/PDNA_Volume_A.pdf).
- [21] Nelson, Andrew, 2017. *Prestigious Houses or Provisional Homes? The ghar as a Symbol of Kathmandu Valley Peri-Urbanism*. *Himalaya*. 37(1).
- [22] Nepal Reconstruction Authority (NRA), 2015. *Earthquake Damaged Private Housing Reconstruction Grant Distribution Procedure, 2072*. <http://www.nra.gov.np/np/resources/details/hcYy-4gv6Oo4ic9-Qti7lq9ekcnj4fuj9OOriuMsGV8>.

- [23] Ninglekhu, Sabin, 2017. 'Inauthentic' Sukumbasi: The Politics of Aesthetics and Urgency in Kathmandu. *Himalaya*. 37(1).
- [24] Parajuli, Lokranjan, 2016. Flawed Category. *The Kathmandu Post*, May 26. <https://kathmandupost.ekantipur.com/news/2016-05-26/flawed-category.html>.
- [25] Sijapati, Bandita, & Limbu, Amrita, 2017. Governing labour migration in Nepal: an analysis of existing policies and institutional mechanisms. Himal Books, Kathmandu.
- [26] Suji, Manoj et al., 2020. Reconstructing Nepal–Bhaktapur: Heritage and Urban Reconstruction, Working Paper. Social Science Baha, Kathmandu. <https://soscbaha.org/publication/reconstructing-nepal-bhaktapur>.
- [27] The Asia Foundation (TAF), 2016. Nepal Government Distribution of Earthquake Reconstruction Cash Grants for Private Houses: IRM – Thematic Study November 2016. <https://asiafoundation.org/wp-content/uploads/2016/12/Nepal-Govt-Distribution-of-Earthquake-Reconstruction-Cash-Grants-for-Private-Houses.pdf>.
- [28] Toffin, Gérard (ed.), 2016 (1991). *Man and His House in the Himalayas: Ecology of Nepal*. Vajra Books, Kathmandu.



## Displaced and Landless Issues in Reconstruction

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*Key words: Displaced, landless, land policy provisions, relocation, reconstruction.*

### Abstract

The community-led relocation and rehabilitation program in Nepal was very successful. It addressed land issues, especially relating to displaced (vulnerable) settlements and landless beneficiaries who had been excluded from the reconstruction grant due to the compulsory requirement of needing proof of land ownership. The National Reconstruction Authority (NRA) drafted bills, regulations, procedures, guidelines and directives incorporating inputs from local representatives and stakeholders for the relocation of displaced and landless beneficiaries. The NRA displayed flexibility amending the policies, laws and regulations for relocating and rehabilitating displaced and landless people affected by the 7.8 Mw Gorkha, Nepal earthquake of April 2015. Two major factors were behind the successful relocation and rehabilitation; first, people were given the choice to decide whether they wanted to relocate as a group or individually, either on government or private land; and second, transfer of authority from the NRA to the local level with strong monitoring and support. This paper has attempted to analyze community-led relocation and rehabilitation of displaced and landless households during reconstruction. It discusses the issues faced by displaced and landless beneficiaries and the NRA, and the efforts of displaced and landless people to relocate and restart their lives after the earthquake.

### 1. Introduction

The NRAs policy relating to “owner-driven housing reconstruction” to effectively address the destruction caused by the Gorkha, Nepal earthquake of April 2015, required proof of land ownership as a condition for owners of private houses to qualify for the rebuilding grant scheme (Amnesty International, 2016, p.7, NRA 2016). The policy did not account for the fact that 25 percent of Nepal’s population was landless or near-landless (CSRC, 2016, CBS, 2011). Due to this policy even NRA record in 2016 showed that around 5,000 potential beneficiaries who had been displaced and 16,000 landless households were unable to

receive the Government of Nepal grant made available through the NRA for housing reconstruction. In the beginning NRA failed to recognize Nepal’s informal and feudal land tenure system, which was the main obstacle to making land grants to people who were landless, sharecroppers, tenants, informal habitants, tillers of guthi (trust) land, etc. (Amnesty, 2017). The requirement of land owner certificates deprived a large number of beneficiaries, mostly Dalits and indigenous people from receiving the NRA grant, even though by March 2017 the Authority had begun claiming that there had been much progress in reconstruction. Land issues in Nepal were diverse but the NRA’s general policy, procedures and guidelines failed to account

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for the issues faced by displaced and landless people affected by the earthquake.

The Post Disaster Need Assessment (PDNA) report said that “[d]ifferent tenure systems (among them, statutory, customary, religious and informal, urban and rural) co-exist in Nepal”, with three categories of official land tenures (state-owned land, private land and guthi land which is owned by trusts and community groups) and “several religious and traditional types of tenure that are not recorded in the land register; informal and squatter settlements, as well as dual ownership with tenancy (Amnesty 2017, p. 18) .

There were also grievances on the issue of land ownership certificates that was linked to eligibility for the NRA grant. The house of Chandra Sunar, a resident of Manahari Rural Municipality-4, Makwanpur district was completely destroyed by the earthquake. She had no land and was unable to obtain the support offered, despite being listed on NRA’s cash grant list. She spent four years in a transitional shelter. She said,

*Our house was completely destroyed by the earthquake. The data collectors had included our name in the list as well. In hope of signing the cash grant agreement soon, I submitted all our credentials and documents to our ward office. They requested for the land ownership certificate as well. But being a landless we were not provided with any tranche for the housing reconstruction. (DS II (PIN/CSRC), field visit note, Makawanpur district, November, 2016)*

A study by NRA to identify vulnerable settlements after the earthquake, said 2,751 families from 112 communities needed to be relocated to safer places. In early 2019, this number had increased to 3,800 families (Displaced Solutions, 2019, p. 14). Even though the NRA claimed that it was addressing the land issues, the approaches were not practicable for the displaced and landless as they were unaware of the decisions and also because it was not a priority of downstream institutions and offices. The Earthquake Affected Beneficiaries Land Registration Procedure 2072 (2016) para 4 provided for the formation of Land Registration Committee at the

district level, chaired by the Chief District Officer (CDO) with the Local Development Officer (LDO), District Forest Officer (DFO), District Chief Surveyor (DCS) and Chief Land Revenue Officer (CLRO) as members. These institutions did not prioritize the relocation of displaced and landless households. The displaced and landless people had aired their grievances at an interaction organized by the NRA and Community Self Reliance Centre data on landless beneficiaries, April 2019 and NRA data, April 2019. Accordingly, the institutions were busy with regular work and as a result, the committee for land registration remained passive and more than 17,000 displaced and landless households remained deprived from the NRA grant.

Secondly, there was no list of displaced people needing relocation or rehabilitation. The NRA had not identify these beneficiaries till April 2017. The locations where these people resided were unsafe and they were living somewhere else after the earthquake. Therefore, the issue was about identification, without which it was not possible to begin the process for the relocation and rehabilitation. This resulted in heavy criticism from the media and from the displaced and landless people and other local stakeholders (including political parties). Thirdly, till April 2017, the NRA had no procedure and guideline in place to address the issue of relocation and rehabilitation of displaced and landless households. Finally, the people who were displaced and landless had diverse issues and therefore the NRA guidelines and procedures were unable to account for all the diverse considerations required for relocation to safer locations.

### 1.1 Community-led relocation and reconstruction

The aim of community-led relocation and rehabilitation is to ensure the public interest, accountability, transparency, and people’s participation in the process. The concept is open to a variety of perceptions and implementation models. The word community-led has been used differently such as community-based, locally owned, community-driven, etc. (Crawford and Morrison, 2018, p. 8). Irrespective of the name,

community-led reconstruction emphasizes the need to rebuild communities, not only houses, with community participation in the whole process of relocation and reconstruction of houses and inclusive engagement of people from the community. Community-led reconstruction and relocation also includes accountability and transparency of whole relocation and rehabilitation process. It aims to integrate local experiences, expertise and social capital with an emphasis on the causes of vulnerability (Crawford & Morrison, 2018). A community-led process also seeks public and collective participation for the relocation and rehabilitation of those displaced and landless and is one where the governance approach should be controlled and decisions made by the people – not by the NRA or federal government or other external stakeholders (Zhao, 2014). It is also a political rather than being a market or bureaucratic approach. The initial NRA policy and procedure took the bureaucratic approach and later shifted to the community-led relocation and reconstruction approach. In Nepal most policies and programs are influenced by the neo-liberal and bureaucratic approach, and it was not surprising for the same procedures to be employed while formulating the initial relocation and reconstruction policies (Basnet, 2016). The displaced and landless households were largely excluded from this and therefore did not own the process, and remained as passive recipients.

Power is integral to every governance system. In the case of relocation and rehabilitation of the displaced and landless, decisions were largely products of the interaction of interests of three sides – government officials, political parties and leaders. The community-led or participatory relocation and rehabilitation process recognized active participation and choice of eligible households for relocating and rebuilding houses. Governance is not only decision making, it is also about mobilizing people and inclusion of voices or decisions of targeted beneficiaries. In other words, community-led or participatory relocation and rehabilitation is self-governed by citizens rather than being controlled by government officials on behalf of the citizens' (Hendriks, 2010:2).

## 2. Methodology

Both primary and secondary data were used in the research. Primary data were generated from the field by using a format for identifying displaced and landless households (quantitative), and key informant interviews, case studies, focus group discussions and observation (qualitative). Secondary data were generated through critical reviews of related NRA policy, acts, guidelines, procedures, and reports. Similarly, also reviewed were reports produced by various international and national non-governmental organizations (I/NGOs), and media. Since the authors were also involved in facilitating a relocation and rehabilitation program, they worked closely with NRA executive members, officials, the displaced and landless households and other stakeholders. The information used also includes data from personal memory at the workplace, and from field notes. The data was triangulated by using information generated from one informant on one issue to regulate that from multiple informants, and information collected using one technique was also cross checked through the use of another technique.

## 3. Defining the displaced and landless households

### 3.1 Displaced households

There is no universal definition of earthquake displaced and landless people. There are different kinds of displacements, by government projects, floods, landslides, earthquake, Tsunami, etc. This paper has reviewed a few definitions used by different institutions and individuals to discuss displacement and landlessness. The United Nation Office for Disaster Risk Reduction (UNDRR) defines displacement and disaster as: "A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses

and impacts (IDMC 2019:9).” This definition focuses on the hazardous events, and vulnerability and capacity (Displaced Solutions, 2019). The International Displaced Monitoring Centre (IDMC) report said disaster displacement depends on three factors: the intensity of the hazardous event, the exposure of people and assets to it and their vulnerability. The Nansen Initiative’s Protection Agenda has defined disaster displacement as: “Situations where people are forced or obliged to leave their homes or places of habitual residence as a result of a disaster or in order to avoid the impact of an immediate and foreseeable natural hazard. Such displacement results from the fact that affected persons are (i) exposed to (ii) a natural hazard in a situation where (iii) they are too vulnerable and lack the resilience to withstand the impacts of that hazard (IDMC 2019:9)”

Clause 2 of Nepal’s Resettlement and Rehabilitation Vulnerable Area Procedure, 2017 has defined vulnerable area as being the area certified by geological survey report of NRA and the need to relocate the settlement of this area to safe place. Similarly, clause 3 of the procedure defined beneficiaries as households or families included in the beneficiaries list by the NRA for construction of private houses. Clause 4 also defined the term beneficiaries to refer to those households or families living in vulnerable areas but are not included as beneficiaries of earthquake affected households. The geological survey carried out by NRA said 4011 families from 21 districts and 99 local government jurisdictions needed to be relocated to a safe place (NRA, 2020, CSRC, 2020). These families have been defined by the NRA as “families residing in risk areas”.

In April 2017, the NRA drafted a procedure and guideline for the displaced, landless people and it had not identified or had an estimate of such households. The Land and Geo-hazard Assessment Unit started the work for the identification of displaced families in April 2017. The NRA hired two geologists with the support of Durable Solutions (CSRC/PIN) from August 2017, which was about the time the Executive Committee started the process of approving displaced

beneficiaries. The procedures and guideline 2017, categorized displaced beneficiaries in three groups – those where there was no need to relocate, those where only support was required to protect the area of residence, and those relocated elsewhere or those whose original place of residence is unsafe for housing reconstruction. Using this guideline, NRA geologists and officials identified the displaced people sought approval for support from the NRA Executive Committee.

### 3.2 Landless beneficiaries

There is no common definition of the landless, or landless beneficiaries, even government acts and regulations have defined them differently at different times. Similarly, I/NGOs and the people in general also have different understandings of the landless people. The Land Reform Act, 1964, (eighth amendment, 2019) has defined the landless and squatters in para 52 B as: (a) Landless/Squatter or Bhoomihin/ Sukumbaasi for the purpose of executing the objective of providing land. Landless/ Squatter refers to a person who does not possess any land under his own ownership or that under ownership of any family member and is unable to manage land through own or family income or by any other effort. This word also refers to the all family members who depend entirely on him/her. (b) for the purpose of section 52(b) and 52(c) the word family refers to the husband, wife, father, mother, daughter and son of the landless squatter and informal settlers (abyabsthit basobasi). It clarified that the definition would not apply for members already separated with their inheritance and engaged in their own livelihood activities. Similarly, 52C has provided for managing informal settlers, where (a) Informal settler refers to the individual who has been residing and operating in unregistered (aailaani parti land) or land indicated as forest area in government records and categorized under the subsection (3). This word also refers to the family members who depend on him/her. The term aailaani jagga refers to land that may or may not be registered under the government’s name or the land being operated for a long time even though it is

indicated as forest area in the government records or currently granted permission for operation.

Further, there is also no uniformity in the way different Government commissions have defined the landless. NRA defined them in its Procedure of Earthquake Affected Private Housing Grant Procedure (first amendment) 2075 (2019) as those who had no land certificate for three generations in their families. Regarding the displaced landless beneficiaries, they were understood to be people displaced by any kind of natural calamity whose area of residence was declared as unsafe for residence by any official report and had recommended relocation to a safe place. In the case of Nepal, NRA said even though the location of residence was unsafe, the people who had owned safe land elsewhere were not regarded as displaced landless beneficiaries. The definition of displaced and landless is also contextual. The NRA definition was also different than that in other countries or adopted by different land-related commissions.

As per the NRA records 9420 had initially been categorized as landless households but later more than 16,000 households could not sign grant agreements for lack of land ownership certificates. Some local Community Based Organizations (CBOs) working on land issues had lobbied for landless beneficiaries to be recognized as displaced. For this purpose, the NRA drafted and amended a grant distribution guideline that was approved by the Council of Ministers. Based on this, NRA and Durable Solutions II, (a program jointly facilitated by Community Self-Reliance Centre and People in Need) collected data of landless beneficiaries and this set off the process of identification and approval of such beneficiaries by the NRA Executive Committee and District Reconstruction Coordination Committees.

## 4. Results and discussions

### 4.1 Policy formulation and implementation

The main laws guiding reconstruction was the Earthquake Affected Structural Reconstruction Act

2072 (2015) and regulations, 2072 (2016). This Act and regulations guided other policies, procedures, and guidelines. The law and regulations provided the basis for establishing the NRA and assigning or forming central and district level implementing institutions. The Land Acquisition for Reconstruction of Earthquake Affected Structures 2072 (2016) and Land Registration for Earthquake Affected Beneficiaries Procedure 2072 (2016) helped to address some issues related to guthi land and tenancy but did not address the issue of landless beneficiaries who had been living in public land for generations. Similarly, the Earthquake Affected Private Housing Grant Distribution Procedure (first amendment) 2073 (2017) had provisioned for the grant and its tranches for eligible households and it had provisioned NRs 200,000 for displaced beneficiaries who wanted to relocate. The most important legal instruments relating to displaced beneficiaries were: the Vulnerable (Geo-hazard prone) Settlement Relocation and Rehabilitation Procedure, 2073 (2017) and the Land Buying Procedure for Earthquake Affected Beneficiaries Guideline (displaced) 2074 (2017). These instruments were vital for successful community-led relocation and rehabilitation of displaced and landless households. These two procedures and guidelines explained the process of relocation and rehabilitation of displaced landless households and were supportive of both relocation and rehabilitation. Clause 2 of the procedure defined the displaced or vulnerable community and beneficiaries, and clause 3 explained the identification procedure of such households. The same guideline provided the displaced households choice to either to buy land or request government to provide public land. Since, getting land from the government involved a long process, many displaced households began buying land at safe locations and started rebuilding houses (NRA, 2017).

Another important decision and procedure was the Earthquake Affected Private Housing Grant Distribution Procedure (2073), (first amendment) 2075 (2019) that had provisioned for providing NRs. 200,000 to landless households and gave them the choice to decide if they wanted to relocate or rebuild at the original place. The NRA policy, act and guidelines were



amended and/or enacted several times to address the issue of displaced and landless beneficiaries based on on-ground experiences (NRA, 2019). On 4 February 2019, the Council of Ministers approved the Earthquake Affected Private Housing Grant Distribution Procedure (2073) (first amendment) 2075 (2019). It provided two options to earthquake affected landless households. The first option allowed landless households to relocate with a maximum of NRs. 200,000 as land grant (for this the beneficiary list needed approval of the Executive Committee) like the displaced landless people. The

second option, was to allow landless beneficiaries to continue staying in place of original residence (forest/public land) where they had been living for generations, and this list of beneficiaries required approval by the District Coordination Committee (DCC) (this committee had Member of Parliament – chairperson, CDO, LDO, and other local authorities as members). This policy allowing reconstruction of houses in the original place of residence allowed more than 90 percent of landless people to rebuild in the original place of residence.

Table 1: Displaced beneficiaries relocated in safe locations (June 2020)

S.N	District	Single Land Ownership			JLO	Ethnicity				
		M	F	Total		Dalit	Janajati	B/C	Others	Total
1	Gorkha	99	136	235	126	33	328	0	0	361
2	Dhading	19	13	32	297	0	329	0	0	329
3	Gulmi	39	11	50	0	50	0	0	0	50
4	Lamjung	8	5	13	14	0	27	0	0	27
5	Parbat	7	9	16	0	15	0	1	0	16
6	Baglung	4	6	10	0	10	0	0	0	10
7	Syangja	11	6	17	1	2	0	16	0	18
8	Rasuwa	92	36	128	538	5	627	34	0	666
9	Nuwakot	25	31	56	161	3	213	1	0	217
10	Sindhupalchowk	38	18	56	265	51	235	33	2	321
11	Kavrepalanchowk	3	2	5	33	12	25	1	0	38
12	Okhaldhunga	13	16	29	76	25	76	4	0	105
13	Ramechhap	4	13	17	94	26	62	23	0	111
14	Sindhuli	0	1	1	7	8	0	0	0	8
15	Solukhumbu	1	4	5	23	5	19	4	0	28
16	Dolakha	0	0	0	28	0	27	1	0	28
17	Chitwan	9	9	18	44	1	61	0	0	62
18	Lalitpur	3	0	3	8	0	9	2	0	11
19	Makawanpur	1	2	3	19	3	19	0	0	22
	<b>Total</b>	<b>376</b>	<b>318</b>	<b>694</b>	<b>1734</b>	<b>249</b>	<b>2057</b>	<b>120</b>	<b>2</b>	<b>2428</b>

Source: National Reconstruction Authority and Durable Solutions, April 2020

Note: M- Male, F, Female, JLO, Joint Land Ownership

## 4.2 Relocation and rehabilitation of displaced and landless households

### 4.2.1 Relocation of displaced households

The NRA began identifying displaced people in July 2017 after which the relocation process had begun to gather speed. The resulting displaced-friendly and community-led relocation process made it possible for large numbers of displaced households to be relocated and rehabilitated in safe locations. Table 1 reports the progress up to June 2020.

Table 1 shows that the highest numbers of households relocated in safer place were Janajati (2057) and Dalits (249) dalits and lowest were Brahmin/Chhetri. The total number of households relocated was 2428. This indicated that the Brahmin/Chhetri were living in safer places compared to the Janajati and Dalits, And that more Janajati and Dalits were landless compared to Brahmin/Chhetri. The table also shows that government policy made it possible for 1734 women to obtain joint land ownership certificates. The NRA procedure and guidelines had recognized women's

participation in relocation. The NRA had displaced households located in 22 districts but in April 2020, the progress in relocation had been reported in 19 districts. Among the 2428 displaced households relocated, 49.67 percent had rebuilt their houses in March 2020.

### 4.2.2 Landless beneficiaries relocated

The community-led relocation process gave landless households the option to relocate or remain at a safe place in the original location. This resulted in 11,115 applications from landless households from 11 districts submitting applications to the NRA Executive Committee and District Reconstruction Coordination Committees seeking approvals for reconstruction grants. Table 2 shows the list of landless households that wanted to relocated to other safe places.

As provisioned in the procedures and guidelines, Grant Management and Local Infrastructure (GMaLi) offices and DS generated the data and applications from landless beneficiaries. Till April 2020, 9,989 landless households had decided to remain at the place

Table No 2: Landless beneficiaries allowed to rebuild houses in place of origin:

SN	Districts	Total Landless families	Landless families allowed to reconstruct houses in place of settlement	Family details
1	Gorkha	44	44	88
2	Dhading	55	55	252
3	Tanahun	200	133	594
4	Nuwakot	17	0	0
5	Sindhupalchowk	25	8	50
6	Kavrepalanchowk	172	154	517
7	Sindhuli	3904	3104	10,546
8	Dolakha	3	0	0
9	Makawanpur	5056	4916	7364
10	Lalitpur	309	196	931
11	Chitwan	1330	1379	1944
<b>Total</b>		<b>11,115</b>	<b>9989</b>	<b>22,286</b>

Source: Community Self Reliance Centre, data on landless beneficiaries, April 2019 and NRA Data, April 2019

of origin and had acquired housing grant from NRA for reconstruction. These people were rehabilitated in place of origin, on government land where they had been living for generations.

#### 4.2.3 Landless beneficiaries relocated to safe locations

Landless households who opted to relocate in locations away from their original residence purchased land elsewhere to build houses. There were 495 such households.

Those opting for relocation, 495 landless households, had moved within six months of the decision allowing them to move. There were 223 Janajati households, 211 Dalit households and 56 Brahmin/Chhetri households that opted for relocation.

#### 4.3 Factors contributing to success in relocation and rehabilitation

This section discusses various factors that had contributed to the success of relocation and rehabilitation. These included,

Regular site visits and interactions with district level stakeholders: NRA and Durable Solutions organized regular orientation and interaction programs on policies, rules and procedures for relocation and rehabilitation. District level officials said the interactions had assisted them to remove confusions about the provisions. The site visits had also served as subtle pressure on district level officials and stakeholders to expedite the processes for relocating and rehabilitating landless households.

Table 3: Landless beneficiaries relocated to other safe locations

SN	District	Single land ownership			JLO	Total progress	Ethnicity				
		M	F	Total			Dalit	Janajati	B/C	Others	Total
1	Gorkha	28	29	57	42	99	47	42	8	2	99
2	Dhading	5	11	16	27	43	20	22	1	0	43
3	Tanahu	5	3	8	0	8	5	2	1	0	8
4	Kaski	0	0	0	3	3	2	0	1	0	3
5	Palpa	0	1	1	0	1	0	0	1	0	1
6	Syangja	0	2	2	4	6	5	0	1	0	6
7	Rasuwa	3	4	7	11	18	13	5	0	0	18
8	Nuwakot	35	33	68	64	132	53	59	19	1	132
9	Sindhupalchowk	11	7	18	17	35	15	15	5	0	35
10	Kavrepalanchowk	7	13	20	31	51	16	22	11	2	51
11	Solukhumbu	0	0	0	5	5	5	0	0	0	5
12	Sindhuli	2	2	4	10	14	10	4	0	0	14
13	Ramechhap	2	3	5	3	8	3	3	2	0	8
14	Okhaldhunga	0	3	3	9	12	5	4	3	0	12
15	Khotang	1	0	1	0	1	0	1	0	0	1
16	Makawanpur	4	6	10	31	41	9	29	3	0	41
17	Lalitpur	4	5	9	9	18	3	15	0	0	18
	Total	107	122	229	266	495	211	223	56	5	495

Source: National Reconstruction Authority and Durable Solutions 2020

Note: M- Male, F, Female, JLO, Joint Land Ownership

**Owner driven land purchase:** The guideline gave landless households the authority to seek land and finalize purchase negotiations with the landowner. These allowed the landless households to decide if they wanted to reside in urban areas or remain in rural areas near farmlands they could continue farming. Chandra Sunar of Manahari, Makawanpur, built a house after obtaining land. She said,

*The (past) four years have been torturous... Now, that has changed. After completion of latrine, we will move in to our new house. The problems that I faced as a landless person, will never be faced by my children.*

**Regular amendment of policies, procedures and guidelines:** The NRA Executive Committee amended its policies, procedures and guidelines to account for feedback received from site visits and interactions with landless households and local stakeholders. At one meeting a field staff of a development agency had informed NRA that 190 households of Category 3 (displaced beneficiaries) had been building houses on neighbor's land with either written or verbal consent of the landowner but had not received the reconstruction grant. The 119th Executive Committee meeting took the decision to provide land purchase grants to 148 households in Sindhupalchowk district. The Executive Committee also addressed other cases that had specific issues that needed resolution.

**Government and NGO partnership:** Durable Solution supported NRA in the relocation of displaced and landless households. It worked with the NRA and its district offices District Level Project Implementing Unit (DLPIU) Grant Management and Local Infrastructure (GMaLi). Durable Solutions collected field level data and supported the identification of displaced and landless households, and throughout the process of relocation. At the community level, the NGO staff assisted landless households in the identification of land and relocation, including the process of land and grant transfer.

Formation of District Reconstruction Coordination

**Committee:** The NRA had decentralized its work and authority and had formed district level committees. A committee was chaired by a member of the federal parliament from the district and included district level stakeholders. This committee played a crucial role in making decisions on people who wanted to rehabilitate at the original place of residence or relocate.

#### 4.4 Best practices

The following section discusses some best practices observed in the rehabilitation and relocation of landless households after the earthquake.

**Transfer of decision-making to beneficiaries:** NRA had adopted community-led, displaced and landless-households driven relocation and rehabilitation process. Its procedures and guidelines allowed beneficiaries to buy land based on their need and capacity. The provision not only engaged the landless but also encouraged them to top up the government grant for making land purchases and building houses. An impact report prepared by Durable Solutions in 2020 said 65 percent relocated beneficiaries had said that their access to services had improved and 98 percent said that they felt safer in the place they had relocated.

**From displacement to rehabilitation:** Sep Gaon in Sindhupalchowk was severely affected by the 2015 earthquake that had destroyed all the houses there. One villager from the village had attended an orientation program organized by the Durable Solutions on the NRA provisions on relief and relocation for displaced families. This set off local discussions on ways to acquire land within the grant budget ceiling of NRs. 200,000.

After several months of search, 19 households jointly acquired 0.1 hectare of land in Kafledanda, Sindhupalchowk, with support from Durable Solutions for documentation and land registration.

Oxfam Nepal then stepped in to build an integrated settlement for the 19 household on the land. The villagers believe that a geologically stable plot would prevent the type of suffering the village had endured after the earthquake. Upon completion of construction,



each household will own a 3-room earthquake resistant house. The price of land has also increased and they think that living in a safer place would be better.

**Money provided to seller of land:** The NRA land grant was provided to the seller of land and not the landless households, which assured the government that money was spent as intended.

**Strong monitoring:** The NRA was not directly involved in the purchase of land but focused on strong monitoring and review of the land acquisition process to discourage fraud and corruption. It had even disqualified some plots that had been selected by local beneficiaries. The NRA assessed the stability of the land as well as its legal registrations. Allowing landless households and local level officials to identify land for relocation/ rehabilitation assisted to speed up the process of relocation. Local officials Ward chair, survey officer, GMaLi officials, representative of Durable Solutions and in some cases a representative of District Coordination Committee – assisted landless households finalize the land acquisition process.

**Development of locations for relocation/ rehabilitation:** The displaced and landless households had selected places without basic services for relocation. These areas had no electricity, water supply, road access, etc. but the local government involvement in the process had assured the provision of facilities like electricity, water supply and road. Land with the services available would have been unaffordable within the grant budget. Further, the fact that Ward chairpersons themselves had to relocate assisted in drawing local government attention for providing basic services.

**Joint land ownership:** The NRA recognized and encouraged women's participation in the relocation and rehabilitation process. The NRA guidelines required relocating/ rehabilitating couples to compulsorily have joint land ownership certificates. This provision enabled women from over 3000 households to own land. This was a major change because a large number of women in Nepal do not have household property registered in their names. Land obtained with NRA support cannot be sold for 10 years.

Other best practices observed during the relocation/ relocation processes were respect of local culture, which was possible because it was a community-led process. The right of owners to select land also contributed to this process and most of the displaced and landless households made choices considering their culture and religion. The beneficiary households also considered their livelihood options while making the selection of land. In general, most people had acquired land close to their original place of residence and this did not distance them from existing livelihood practices. Finally, another good practice was the labor-exchange for supporting each other to rebuild houses.

#### 4.5 Learning

A number of lessons can be drawn from the experience in the relocation and rehabilitation of displaced landless households. The following section summarized some of the lessons.

There are some pre-conditions that determine success of relocation and rehabilitation efforts. Lack of information was a major obstacle in the process, which was bridged by engaging a NGO to inform and orient the local representatives and other stakeholders on the process. Having informed local representatives assisted in the identification of the problems faced by the targeted beneficiaries. It can therefore be concluded that information and orientations on the process are critical for a community-led process to succeed. This includes awareness building of the intended beneficiaries.

The NRA had made verbal commitments to resettle/ relocate landless households and it took a long time for the Authority to decide how this was to be done.. The delay in decision-making created space for various interests (including politicians) to make promised they could not deliver. Formal decisions on such matters are important, which was evidenced by the pace of work after the NRA prepared the formal procedure and guideline and appointed a focal person to oversee the relocation/ rehabilitation processes.

Taking lessons from its work in facilitating private house construction, the NRA, adopted a community-led approach for relocation/rehabilitation that involved sharing the powers to identify and verify displaced and landless households with local governments. Similarly, the NRA and local governments also engaged in monitoring. The power sharing with local governments and NRA district level offices contributed to the success of the relocation and rehabilitation efforts.

The engagement of civil society groups, particularly the National Land Rights Forum and District Land Rights Forums, assisted in mobilizing the displaced and landless households that had facilitated identification and verification processes and actual relocation/rehabilitation. The involvement of civil society also caused the NRA rethink the entire process of relocation and rehabilitation. The mobilization of beneficiary households contributed to keeping watch over the NRA and political parties and to the overall success of the community-led relocation/ rehabilitation.

Finally, involvement and interest of local officials was instrumental to the successful program. For example, a CDO in a district had made calls to the DLPIU (GMaLI) and other stakeholders and asked them to complete reconstruction within deadline, particularly that of displaced landless households. He had also asked them to submit plans of relocation and reconstruction of houses for these households. This helped to expedite the pace of work in the district, which had, however, slowed down after his transfer. Similarly, the pace of work was quicker in local jurisdictions where local officials were supportive. This pace of work also depended on the engagement of the District Reconstruction Coordination Committee with the issue.

#### 4.6 Challenges

The issue of relocating displaced and landless households was challenging. It was difficult to buy safe land near the place of origin of the displaced and landless households. This was important to enable people to

continue with their livelihood practices. Often even if such land was located, it was over the budget available for purchase. Another challenge was ensuring that the relocated/ rehabilitated families had adequate livelihood options, particularly households whose members had been injured and disabled by the earthquake, minor-headed families, single women, and also single males.

The drafting of reconstruction guidelines took two years for the NRA; it took it four years to come up with procedure and guideline for resettling displaced and landless households. Validating the beneficiaries and issuing and reissuing (amendments) also took time. The identification of displaced people was centralized and this contributed to the delays in housing construction. This decision-making at the NRA was taking place even in June 2020, well into the sixth year after the earthquake. Further the cash grant for purchasing land was also inadequate as land prices tended to increase after NRA support was announced.

Other challenges included accessing the displaced/ landless households who lived in remote areas, technical difficulties of land transfers, and delays caused by the unwillingness of survey officials to travel to remote areas to verify land areas before the transfer could be completed.

## 5. Conclusions and recommendations

### 5.1 Conclusions

Community-led relocation and rehabilitation process proved to be more efficient than a government-led approach, and was also cost-effective. An impact report discussed earlier showed that 65 percent of relocated households had access to improved services and 98 percent beneficiaries reported feeling safer at the place they had relocated. The relocation and rehabilitation was one of Nepal's successes in the reconstruction process, which was made possible by the flexibility at NRA, involvement of targeted beneficiaries and engagement of civil society organizations in facilitating the processes.

## 5.2 Recommendations

The following are recommendations that could assist relocation rehabilitation efforts after disasters.

**Make local governments responsible:** The relocation/ rehabilitation efforts were delayed largely because of the failure to identify who should be responsible for supporting the process. This remained unclear both to local governments and political representatives, and NRA district offices had largely served as “post offices” that passed messages from the NRA to communities and vice-versa. This changed with the transfer of authority and placement of focal officials at the local offices.

**Adopt flexibility to address diversity of issues:** The diverse land and natural resource management issues in Nepal confirmed that universal or blanket policies and regulations would not work, and that there was need for the NRA to be flexible to address the issues in issue-specific ways. This is a practice that would need to be replicated, whenever required.

**Limit changes to the institutional structure and team/staff:** The NRA leadership had changed thrice within four years and structure also changed as many times. Humanitarian work is sensitive and such changes do not contribute to trust-building. It is therefore important to ensure that the leadership and structures of oversight organizations remain stable throughout the humanitarian effort.

**Participatory reconstruction:** At the outset, the NRA did not give enough attention to participatory methods of identifying the displaced and landless households that needed support. There was also little transparency in the methods and processes used for identifying and verifying households that required support. Participatory approaches can assist in overcoming challenges such as that of some beneficiaries with owned land in other locations. This was not addressed in the top-down identification process.

## References

- [1] Amnesty International, 2017. Earthquake and land issues in Nepal. Amnesty International.
- [2] CBS, 2011. Population Census 2011. Government of Nepal, Kathmandu.
- [3] CSRC, 2011. Earthquake and land issue. CSRC.
- [4] CSRC, 2020. Half Yearly Progress Report of DS II.
- [5] CSRC, 2016. Field data compilation report.
- [6] Crawford, G. & Morrison, C., 2018. Build Back Better, Strengthening Social Inclusion and Accountability through Community-Led Reconstruction in Post-Earthquake Nepal. Centre for Trust, Peace and Social Relation, Coventry University, Actionaid Nepal, Helplga, DEC.
- [7] Displaced Solutions. 2019. Lessons Learned from Post-Earthquake Policy in Nepal.
- [8] Hendriks, Frank, 2010. Vital Democracy: A Theory of Democracy in Action. Published to Oxford Scholarship online May 2010.
- [9] NRA, 2015. Census and verification survey data base. Government of Nepal, Kathmandu.
- [10] NRA, 2017. Compilation book of Acts, Procedures and Guidelines. With support CSRC, Oxfam and NLRf.
- [11] NRA, 2019. Council of Minister, Government of Nepal, the Earthquake Affected Private Housing Grant Distribution Procedure (2073), first amendment 2075 (2019).
- [12] NRA, 2020. Geological Survey report/Data base. Central Office Sinhdurbar, Kathmandu.
- [13] Zhao, Y., 2013. China’s Disappearing Countryside, Towards Sustainable Land Governance for the Poor.



## Earthquake Damage Prediction of Buildings in Nepal using Machine Learning Tools

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*Key words: Machine learning, seismic risk assessment, building damage portfolios, building damage prediction.*

### Abstract

Decision-makers and stakeholders require rapid assessments of the potential damages following earthquake events to develop and execute disaster risk reduction strategies and to systematically respond to the emerging situation after disasters. Classical risk assessment methods are both resource and time-consuming. In this study, the crowd-sourced building damage data collected after the Mw 7.8, 2015 Gorkha, Nepal earthquake was used to explore the efficiency of various machine-learning techniques in rapid earthquake-induced building damage assessment. The Random Forest Regressor showed the best performance among several machine learning methods considered in this study. For rapid seismic damage assessment in Nepal, for a given earthquake scenario, building features data collected from the existing built-up environment can be used as an input to this model to derive an output that can help decision-makers to take appropriate decisions.

### 1. Introduction

Even though earthquakes are infrequent they have significant physical and social consequences. On average, since 1990-2017, annually, earthquakes have resulted in around US\$ 34.7 billion losses globally (OECD, 2018) and US\$ 5 billion losses in Nepal (UNDRR, 2019). It is crucial for decision-makers and stakeholders to have rapid assessments of potential damage caused during earthquake events available (Bommer & Crowley, 2006). For a successful emergency response planning before and after an earthquake, the spatial distribution of damage over the built environment is required (Earle et al., 2010; Ranf et al., 2007). Various classical methods exist for estimating earthquake-induced building

damage based on ground shaking. These methods require a lot of information on building portfolios and earthquake ground motion. This makes seismic risk assessment at a regional and urban scale quite challenging because the collection of building information and application of damage assessment methods is time and resource consuming.

Progress in artificial intelligence (AI) tools over the last decade has led to increase in their application in various domains. Yet, there has been very limited number of applications of AI for rapid seismic risk assessment. Riedel et al. (2014, 2018) showed the ability of the Support Vector Machine for seismic vulnerability assessment at urban or regional scales. Mangalathu et al. (2020) showed an application of the machine

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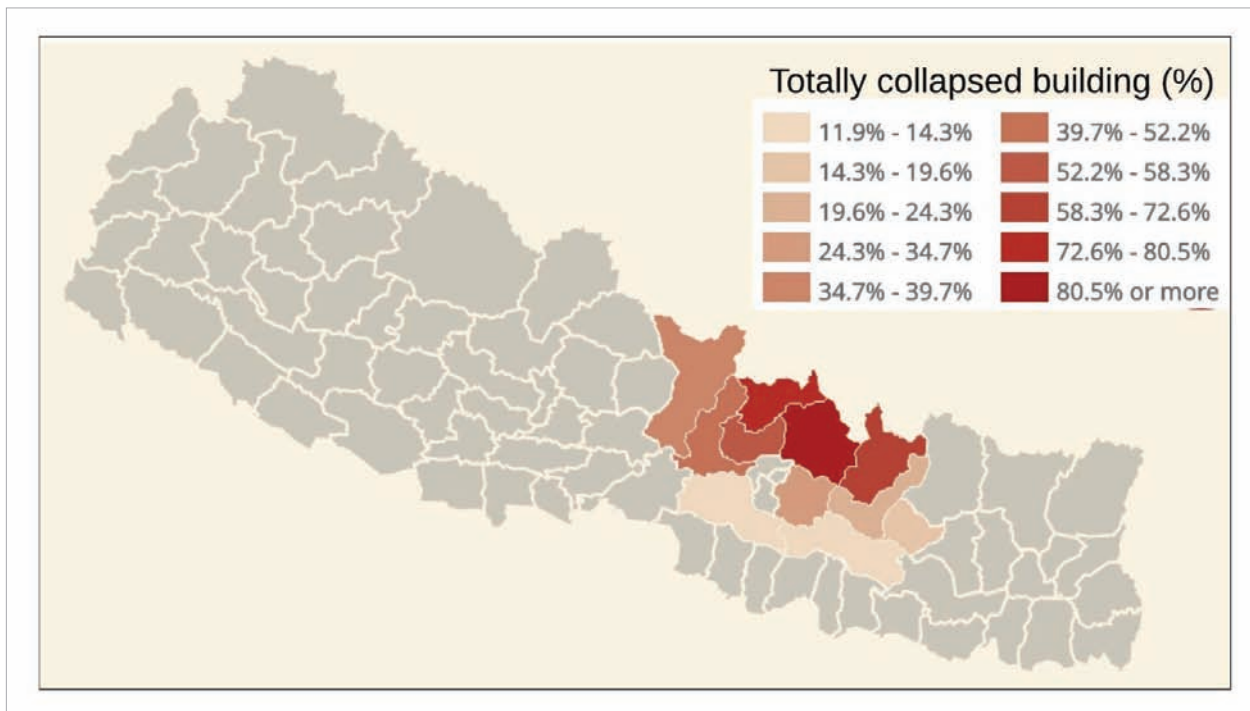


Figure 1. Location of 11 districts where the 2015 Nepal earthquake building damage data are available. It also illustrates the severity of the earthquake effect in each district in terms of the collapsed buildings. (Source: <http://eq2015.npc.gov.np/#/compare>).

learning technique in rapid seismic risk assessment using earthquake damage data portfolio of the 2014 South Napa earthquake. They concluded that the use of the rapidly growing machine learning techniques in rapid seismic risk assessment provides a reliable estimate of the earthquake-induced potential building damage. To assure the use of AI techniques in seismic risk assessment, there is need for investigating both the efficiency and relevancy of the AI technique in seismic damage assessment at a regional scale.

Building-damage portfolios of earthquake events are starting to become easily accessible. For example, the National Planning Commission of Nepal (<http://eq2015.npc.gov.np/>) shared data from a massive household survey of the damaged buildings after the Mw 7.8 2015 Gorkha, Nepal earthquake. The objective of this paper is to test the effectiveness and relevancy of several AI methods for predicting spatially distributed seismic damage. This article presents

the results on the performance of various machine learning models in rapid damage earthquake assessment using the Nepal earthquake damage portfolio.

## 2. Description of the damage database

On 25 April 2015, a devastating earthquake of Mw 7.8 struck central Nepal with an epicenter about 80km NW from Kathmandu, hypo-center depth of 8.2 km, and 120 km rupture length towards the east. Thousands of houses were damaged, around eight million people were affected (8,790 fatalities and 22,300 injuries). The 2015 Nepal earthquake building-damage database consists of 762,106 building datasets collected in 11 districts of Nepal (Figure 1). The severity of damage is grouped into five grades, based on visual inspection. Similarly, the information about each building feature such as number of stories, age of building, height, plinth area, construction material, ground slope

condition, building position with respect to another building, and roof type were also assigned during visual observation. The detailed description of the five damage grades and building features is available on the same website (<http://eq2015.npc.gov.np/docs/#/faqs/faqs>). The geo-localization of buildings was up to the Ward – local administrative unit. In addition, the ground motion data was added to the database from the ShakeMap tool from the United States Geological Survey. In this study, macro seismic intensities (MSI) map from the ShakeMap is considered as an input ground motion (Figure 2) and assigned to all the buildings located in the same ward.

In the database, number of floors range from 1 to 9 (Figure 3a), age from 1-200 years (Figure 3b), plinth area from between 70 to 5000 sq. ft. (Figure 3c), and

height between 6-97 ft. (Figure 3d). The MSI value ranges from 5.30 to 8.30 (Figure 3e). Likewise, 82.89 percent, 13.86 percent, and 3.24 percent of the buildings were located in, respectively, flat, moderate, steep slopes, (Figure 3g). Further, 28.05 percent, 66.10 percent and 7.85 percent buildings were associated with heavy, light, reinforced concrete roofing-system, respectively (Figure 3h). Similarly, 79.31 percent, 16.98 percent, 3.53 percent and 0.17 percent of buildings were stand-alone, one-side-attached, two-side-attached and three-side-attached to another building (Figure 3i). The distribution of the buildings according to damage grades (DG) in the database was: 10.34 percent in DG1, 11.45 percent in DG2, 17.90 percent in DG3, 24.12 percent in DG4, and 36.19 percent in DG5 (Figure 3f).

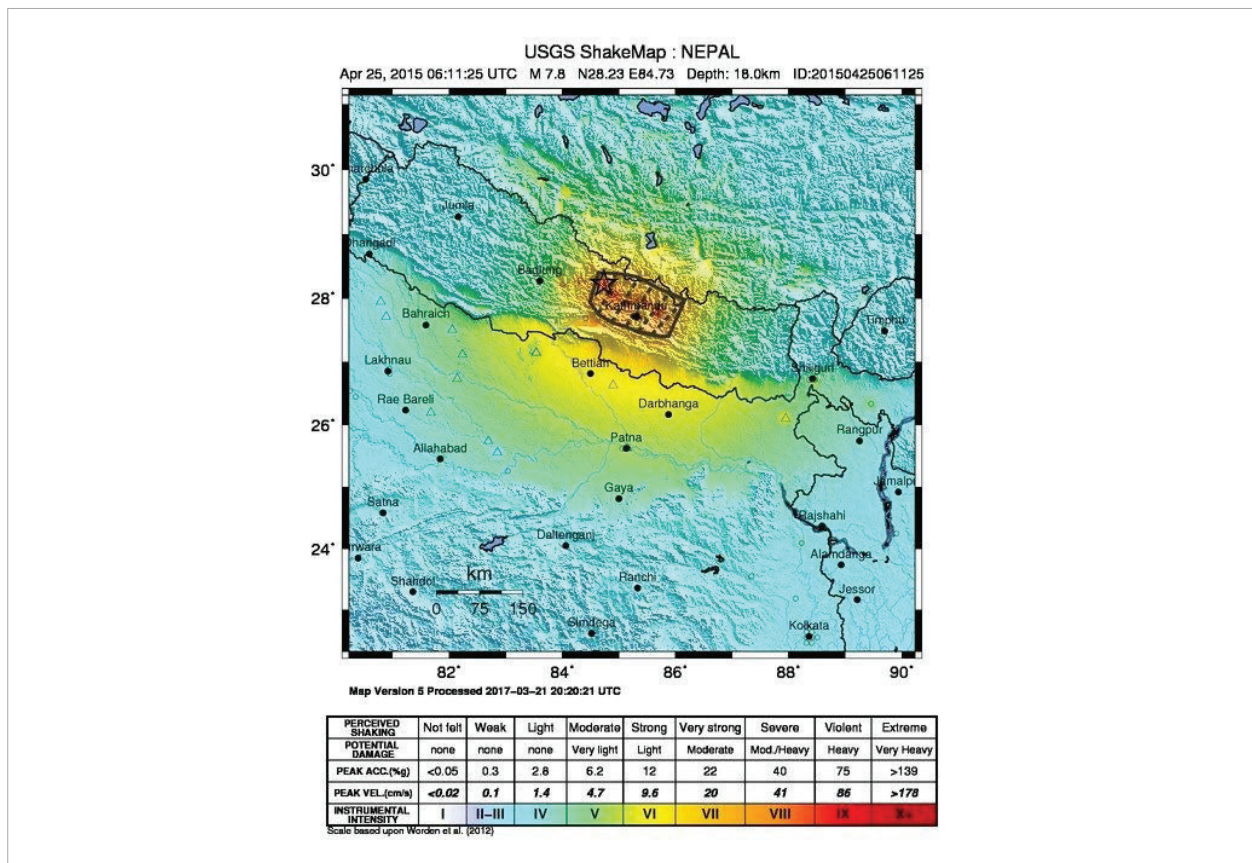


Figure 2. Spatial distribution of 2015 Nepal earthquake ground motion intensity. (Source: <https://earthquake.usgs.gov/earthquakes/eventpage/us20002926/shakemap/intensity>).

### 3. Method

This study assessed the efficiency of Linear Regression (LR), Support Vector Regressor (SVR), Gradient Boosting Regression (GBR), Random Forest Regression (RFR), Gradient Boosting Classification (GBC) and Random Forest Classification (GBC) in damage prediction. A brief description of these methods is provided in the annex. Interested readers are suggested to refer to (Friedman et al., 2001) and scikit-learn machine learning in Python (Pedregosa et al., 2011) for detailed information on these machine-learning methods. In all 0.48 percent of the dataset had missing values. The missing data points associated with categorical

variables (damage grades, ground slope, material, roof type and position) were removed and the missing values associated with the numerical variables (number of stories, age, the height of buildings) were replaced by their respective mean value. The entire dataset was randomly divided into training and testing subsets. Following the recommendation of Friedman et al. (2001), 70 percent of the data is used as a training set and 30 percent as a testing set. The training set was used to train the machine learning model and the testing set to observe the predictive performance of the machine learning model. For each machine-learning model, the features of buildings (number of stories, height, age, plinth area, ground slope condition,

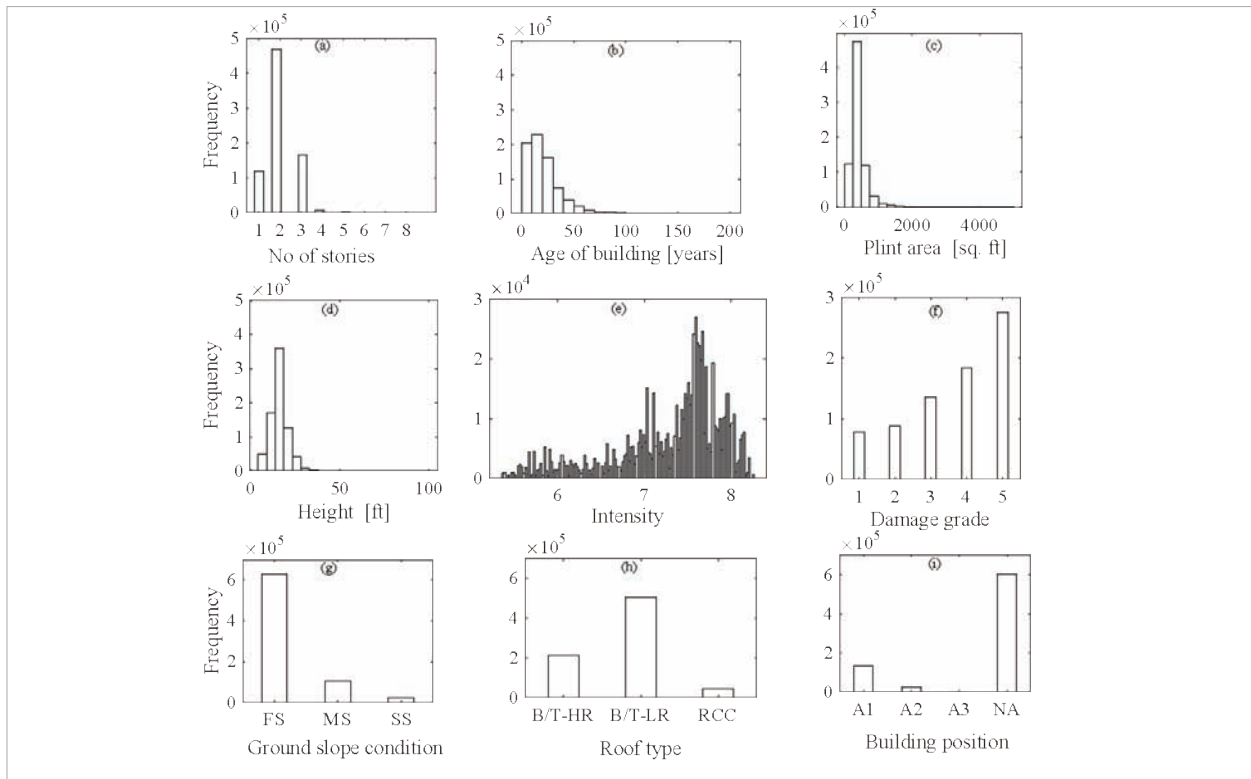


Figure 3. Distribution of different features in the dataset. The y-axis is the frequency and the x-axis in frame is (a) number of stories, (b) age of building, (c) plinth area of building, (d) height of the building (e) macro seismic intensity, (f) damage grade, (g) ground slope condition at building location (h) type of construction material used in roof, and (i) position of building with respect to another building. In frame (g) FS/MS/SS represent flat/mild/steep slope, respectively. In frame (h) B/T-HR, B/T-LR, represent bamboo/timber-heavy-roof, bamboo/timber-light-roof and RCC represents reinforced cement concrete. In frame (i) A1/A2/A3 and NA represent attached with one/two/three sides and not attached, respectively.

position, roof material, construction material), as well as the intensity of ground motion, are defined as input features and damage grades as response variables. The performance of each machine learning model was evaluated through the coefficient of determination ( $R^2$  scores) and Root Mean Square Error (RMSE) scores for regression and accuracy scores for classification problems. Higher the value of  $R^2$ , accuracy score, and lower the RMSE value, the better is the performance of the model.

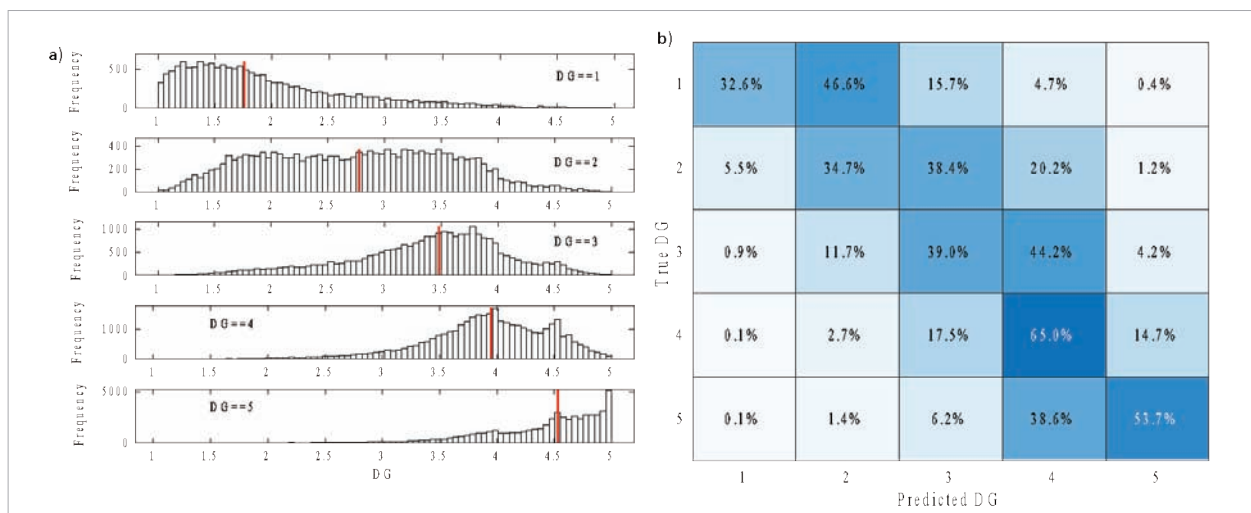
#### 4. Results and discussion

The LR and SVR were observed to have the values of  $R^2$  score equal to 0.41 and 0.38 and RMSE score equal to 1.06 and 1.08, respectively. The lowest  $R^2$  value and the highest RMSE value for LR and SVR methods prove less suitable for this dataset. They oversimplified the complex non-linear interaction among the features in the dataset. Similarly, the GBC and RFC methods were observed to have an accuracy score of 0.33 and 0.55, respectively. GBC and RFC were also unable to classify the true damage grade with high accuracy. The highest values of  $R^2$  score were 0.58 and 0.56, and the lowest RMSE values were 0.88 and 0.87 for GBR and

RFR, respectively. These methods give higher efficiency in damage prediction. GBR and RFR can reproduce the stronger non-linear interaction that exists among different features present in the dataset.

The performance, effectiveness, and computational time of these methods are very sensitive to the value of model parameters (hyperparameters). The GBR method requires careful tuning of a greater number of hyperparameters compared to the RFR. Thus RFR was observed to be the most efficient method in building-damage prediction.

Figure 4 shows the results of the RFR method in the test dataset. Few misclassifications have been pointed out both by considering the frequency of correctly assessed DGs i.e. predicted damage is within one step from the observed value, and the median value of assessed DGs that deviate from the classification provided in the field surveys. This illustrates the high strength of the RFR method in damage prediction, which is very crucial from the perspective of seismic risk assessment. Thus, using RFR model, the spatial distribution of seismic damage can be predicted using the basic features of buildings and building-damage information from the existing post-disaster survey and vulnerability assessment with a reasonable level of accuracy.



**Figure 4.** Graphical representation of the predictive performance of the RFR model on the test dataset. In frame (a) the x-axis is the predicted damage grade (DG) and the y-axis is the frequency. The red vertical line represents the median value. The true damage grade is noted in the same subplot. In frame (b) the x-axis is the predicted DG and the y-axis is the true DG.



## 5. Conclusion

The efficiency and relevancy of machine learning techniques in rapid seismic risk assessment was studied using the 2015 earthquake building damage data from Nepal. Performance of Linear Regression, Support Vector Regression, Gradient Boosting Regression, Random Forest Regression, Gradient Boosting Classification, and Random Forest Classification in building-damage prediction using basic features of building was tested. The RFR was observed to be the most efficient in damage prediction. A reasonable estimate of the damage at a given level of the ground motion is possible using basic features of building and RFR model, resolving the time and resource consumption issues.

The 2015 Nepal earthquake building-damage portfolio and the RFR model can be used for both site specific or global rapid seismic risk assessment in Nepal. In other words, using the RFR model trained on the 2015 Nepal earthquake building-damage dataset, we can predict potential damage for a given earthquake scenario by considering the same input data collected from the existing built-up environment. The output of such an assessment model can assist stakeholders and decision-makers in rapid seismic risk assessment in order to formulate and implement plans and policies in earthquake disaster risk reduction.

The 2015 Nepal earthquake building-damage dataset can be used as a powerful tool for seismic risk assessment in Nepal. The building-damage database is associated with significant amount of noise. Fine refinement of the existing dataset including all available post-disaster building damage data is recommended. Similarly, the development of national building database by collecting key information of building would be needed to facilitate future seismic risk assessments.

Additionally, further investigation in rapid seismic risk assessment should be carried out by considering the key building features (number of stories, plinth area, age, height, etc.) that are easily accessible and could be used as a good proxy to predict building

damage using the most suitable machine learning technique. Investigation of the applicability of the machine learning model with other open-data platforms like OpenStreetMap (OSM) should be investigated for rapid seismic risk assessment.

## Acknowledgement

This work is part of the URBASIS program led by Philippe Gueguen at ISTERre/Université de Grenoble Alpes. We thank LabEx OSUG@2020 Investissements d'avenir-ANR10LABX56 and the ITN-MSCA URBASIS project funded by the EU Horizon 2020 program under Grant Agreement Number 813137. Part of this work was supported by the Real-time earthquake risk reduction for a resilient Europe (RISE) project, funded by the EU Horizon 2020 program under Grant Agreement Number 821115. Additionally, Subash Ghimire would like to thank Kathmandu Living Labs for its assistance during the research.

## References

- [1] Bommer, J. J. & Crowley, H., 2006. The influence of ground-motion variability in earthquake loss modeling. *Bulletin of Earthquake Engineering*. 4(3), 231–248. <https://doi.org/10.1007/s10518-006-9008-z>.
- [2] Earle, P.S. et al., 2010. Prompt assessment of global earthquakes for response (pager): A system for rapidly determining the impact of earthquakes worldwide. *Earthquake Research: Background and Select Reports*. 31–46.
- [3] Friedman, J. et al., 2001. *The elements of statistical learning* (Vol. 1, N). Springer series in statistics, New York.
- [4] Mangalathu, S. et al., 2020. Classifying earthquake damage to buildings using machine learning. *Earthquake Spectra*. 36(1), 183–208. <https://doi.org/10.1177/8755293019878137>.
- [5] OECD, 2018. *Financial Management of Earthquake Risk*. 108. <http://www.oecd.org/finance/insurance/Financial-management-of-earthquake-risk.pdf>.
- [6] Pedregosa, F. et al., 2011. Scikit-learn. GetMobile:

- Mobile Computing and Communications. 19(1), 29–33. <https://doi.org/10.1145/2786984.2786995>.
- [7] Ranf, R.T. et al., 2007. Post earthquake prioritization of bridge inspections. *Earthquake Spectra*. 23(1), 131–146. <https://doi.org/10.1193/1.2428313>.
- [8] Riedel, I. et al., 2014. Macroscale vulnerability assessment of cities using association rule learning. *Seismological Research Letters*. 85(2), 295–305. <https://doi.org/10.1785/0220130148>.
- [9] Riedel, Ismaël & Guéguen, P., 2018. Modeling of damage-related earthquake losses in a moderate seismic-prone country and cost–benefit evaluation of retrofit investments: application to France. *Natural Hazards*. 90(2), 639–662. <https://doi.org/10.1007/s11069-017-3061-6>.
- [10] UNDRR, 2019. Disaster Risk Reduction in Nepal: Status Report 2019. 1–30.

## Annex

### Linear Regressor

Linear Regression (LR) explains the relationship between target variables through a linear combination of input (predictors) variables. The functional form of the LR is given below as:

$$Y = w_0 + w_1 x_1 = w^T x$$

Here, the weight  $w_0$  represents the y-axis intercept and  $w_i$  is the weight coefficient of the input variable, and  $Y$  is the target variable. The LR fits a linear model with coefficients  $w = (w_1, \dots, w_p)$  to minimize the residual sum of squares between the observed targets in the dataset, and the targets predicted by the linear approximation. The LR has simple analytical and computational properties, which provide an adequate interpretable description of how the input affects the output. This method is computationally efficient. The weight associated with each input variable helps in identifying the importance of features. The LR is oversimplified (unable to capture the complexity of the problem), and is very sensitive to outliers. The LR

assumes that data are linearly separable, and is not very efficient for nonlinear data ([https://scikit-learn.org/stable/modules/linear\\_model.html](https://scikit-learn.org/stable/modules/linear_model.html)).

### Support Vector Regressor

Support vector machines (SVM) are a set of supervised learning methods used for classification, regression, and outlier detection. In the SVM, the input features are transformed into a higher-dimensional space where two classes can be linearly separated by a high dimensional space called a hyperplane. The SVM was originally used for classification problems and then extended to regression problems called Support Vector Regression (SVR). SVR maintains all features of SVM. The model produced by SVR depends only on the subsets of the training dataset because the cost function ignores samples whose prediction is close to their targets. Three types of implementation are possible for SVR: SVR, Nu-SVR, and Linear SVR. SVM is effective in high dimensional spaces, memory efficient, and has versatility in kernel functions. This method is more suitable when the number of features is more than the number of data points. SVM is less suitable when the number of data points is large, as this does not provide direct probability estimate, and overfitting could be an issue when the number of features is larger than that of the data points (<https://scikit-learn.org/stable/modules/svm.html>).

### Gradient Boosting

Gradient Boosting (GB) is a generalization of boosting to the arbitrary differentiable loss function. GB is based on an ensemble of several decision trees. A decision tree represents a set of conditions or restrictions that are hierarchically organized and successively applied from a root to a leaf of the tree. The GB is an accurate and effective procedure that can be used for both regression and classification. It has been shown that both the approximation accuracy and execution speed of the GB can be substantially improved by incorporating randomization into the procedure. Specifically,

at each iteration, a subsample of the training data is drawn at random (without replacement) from the full training data set. This randomly selected subsample is then used in place of the full sample to the base learner and compute the model update for the current iteration. This randomized approach also increases robustness against the overcapacity of the base learner. GB has much flexibility in terms of the loss function as it can easily handle missing data, and often works well with categorical and numerical data. This is sometimes computationally expensive, requires careful tuning of hyperparameters (model input parameters). (<https://scikit-learn.org/stable/modules/ensemble.html#gradient-boosting>).

### Random Forest

Random Forest (RF) ensembles the performance of several decision trees to classify or predict the value of variables, which is based on bagging. Decision trees are trained by using a random subset of the original features. The RF can model complex relationships in the data and account for non-linear relationships between predictor and response variables by the adaptive nature of the decision rules. The RF has better generalization performance, is less sensitive to outliers, and does not require tuning of many hyperparameters. It works with continuous and also categorical predictors and also can handle missing data (<https://scikit-learn.org/stable/modules/ensemble.html>).

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