

## SHARED KNOWLEDGE ON EARTHQUAKE RECOVERY AND RECONSTRUCTION: THE NEPAL EEFIT 2022 RETURN MISSION

**Michael Whitworth<sup>1</sup>**, Jenny Pattison<sup>2</sup>, Giorgia Giardina<sup>3</sup>, Diana Contreras<sup>4</sup>  
Rohit Adhikari<sup>5</sup>, Sean Wilkinson<sup>6</sup>, , Fatemeh Foroughnia<sup>3</sup>, Valentina  
Macchiarulo<sup>3</sup>, Paul Jaquin<sup>7</sup>, Paul Burton<sup>8</sup>, Kökcan Dönmez<sup>9</sup>, Guillermo Franco<sup>10</sup>,  
Shuva Sharma<sup>11</sup>, Pietro Milillo<sup>12</sup>, Krisha Chandra<sup>13</sup>, Joshua Jones<sup>1</sup>

<sup>1</sup>Ground Engineering, AECOM, Plymouth, UK, <sup>2</sup>Civil Engineering, ARUP, London, UK <sup>3</sup>Civil Engineering and Geosciences, Delft University of Technology, Delft, Netherlands, <sup>4</sup>Geospatial Science, University of Cardiff, Cardiff, UK, <sup>5</sup>Civil Engineering, University College London, London <sup>6</sup>Civil Engineering, University of Newcastle, Newcastle, UK, , <sup>7</sup>Civil Engineering, eZED, Queenstown, New Zealand, <sup>8</sup>Civil Engineering, University of East Anglia, Norwich, UK, <sup>9</sup>Civil Engineering, Bogazii University, Istanbul, Turkey, , UK, <sup>10</sup>Cat Risk Research, Guy Carpenter, New York, USA, <sup>11</sup>Civil Engineering, SW Nepal, Kathmandu, Nepal, <sup>14</sup>Civil Engineering, University of Houston, Houston, USA, <sup>13</sup>Research, Independent Researcher, India

**Abstract:** *On the 25th April 2015 a magnitude 7.8Mw struck Nepal, followed by two strong aftershocks on the 26th April and 12th May (6.7Mw and 7.3Mw, respectively). Over 9000 people were killed, 22,000 injured with over 500,000 homes either damaged or destroyed, resulting in economic losses of over US\$7 Billion. A key component of understanding the resilience of Nepal to future events is understanding whether Nepal has “Built back better”, developed resilient communities for the future and has in place recovery strategies and preparedness plans. In May 2022 the Earthquake Engineering Field Investigation Team (EEFIT) returned to Nepal. Through a range of approaches including stakeholder workshops, stakeholder questionnaires, social media studies, ludic activities, remote sensing, landslide reconnaissance and revisiting field locations from the 2015 EEFIT mission, the team aimed to investigate the earthquake recovery and reconstruction and evaluate whether Nepal had built back better. The assessment of the societal aspects identified that pre-2015 there was a lack of preparedness among the population, and despite the development of recovery plans this appears to have not been socialised among the community. It has been identified that Nepal is moving from the recovery to the development phase of disaster recover. However, the perception remains that despite reconstruction being advanced, it is far from over, with delays in the recovery and reconstruction not only COVID-19 related. The EEFIT return mission found that overall Nepal is Building Back Better. The mission (a) identified that the landscape appeared to be recovering from earthquake induced landslides with limited evidence of reactivation, (b) found clear evidence of improved standards of school reconstruction, (c) noticed that improved design codes are implemented and (d) observed an increase in a skilled work force. Despite this, seismic vulnerabilities remain.*

### Introduction

On the April 25<sup>th</sup> 2015 at 11:56 (06:11 UTC) the Gorkha earthquake with a moment magnitude scale of  $M_w$  7.8 struck Nepal. It was followed by numerous landslides in the hills and mountains in the affected region (Wilkinson et al., 2019). Around 9,000 people were killed, 100,000 people were injured. Around 500,000 houses were destroyed and another 269,000 damaged, which included historical and cultural monuments recognised as UNESCO World Heritage (WH) Sites (Preventionweb, 2015). Typically earthquake reconnaissance missions (i.e. 2009 L’Aquila earthquake (Tiziana Rossetto et al., 2009), 2010 Haiti (Booth, Saito, & Madabhushi, 2010), Maule, Chile (Lubkowski et al., 2010), 2011 Christchurch, New Zealand (Wilkinson et al., 2011), Tohoku, Japan earthquake (Pomonis et al., 2011) and Gorkha earthquake in Nepal (Wilkinson et al., 2019) focus on the immediate impact of the earthquake, usually in the first few weeks and months at the boundary between the emergency response and short-term recovery phase (Figure 1).

However, it is becoming increasingly recognised that the ability to recover and reconstruct following a major event is critical to the resilience of many countries around the world. As such, the need to understand the Long-Term Recovery from an earthquake can inform the level of preparedness for future events. In 2022 the Earthquake Engineering Field Investigation Team (EEFIT) undertook a return mission to Nepal to understand how Nepal is implementing its recovery programme following the 2015 Gorkha Earthquake.

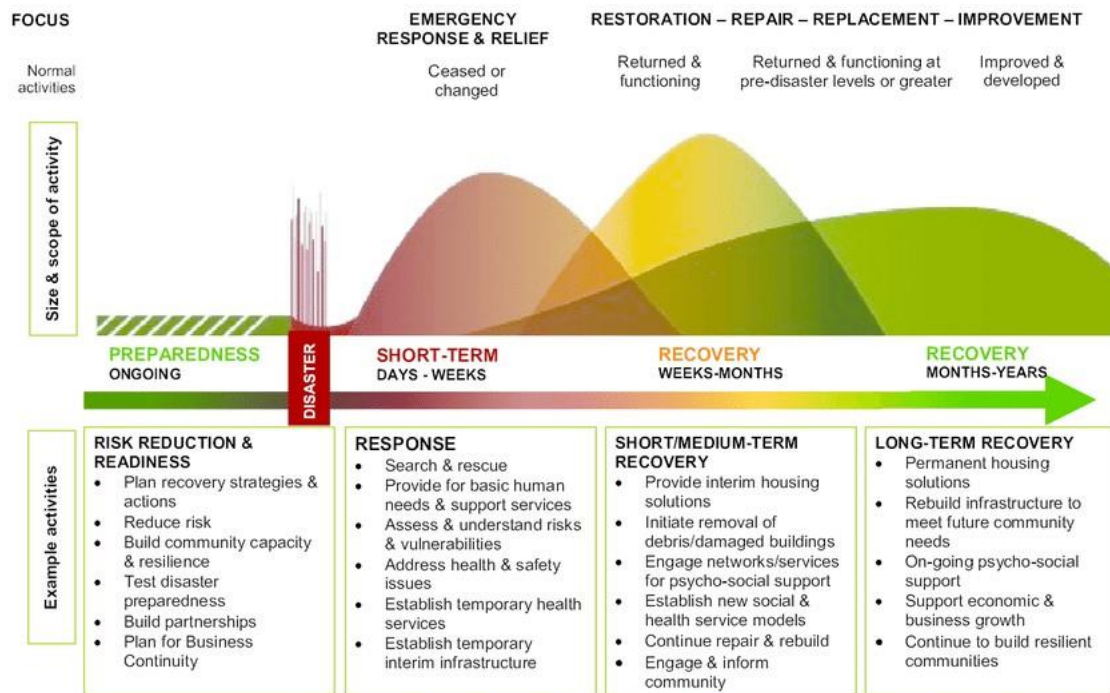


Figure 1. The Disaster Recovery Cycle (FEMA, 2016)

## The 2015 and 2022 Earthquake Engineering Field Investigation Team Mission

An EEFIT field mission was undertaken soon after the Gorkha earthquake between the 12<sup>th</sup> and 20<sup>th</sup> June 2015, with the aim to investigate the impacts of this earthquake, and how it affected Nepalese communities and their economy. The mission had the objectives of (1) obtaining available recorded ground motion data, (2) making observations of the performance of buildings, geotechnical structures and lifelines, (3) assessing the impact of landslides on remote mountain communities, and (4) gaining an understanding of insurance and other economic consequences resulting from this event. The mission visited a range of locations within Nepal including Kathmandu and the surrounding areas, Chautara in Sindoupauchuk 40km to the north east of Kathmandu, Gorkha and surrounding areas including remote communities close to the epicentre (Wilkinson *et al.*, 2019).

In 2022 The EEFIT team returned to Nepal between the 20<sup>th</sup> and 26<sup>th</sup> May to investigate the recovery and reconstruction and Build Back Better approach, analysing both the physical reconstruction and the institutional framework for Disaster Risk Reduction. The main objectives of the return mission were (1) evaluate relocation and reconstruction strategies, (2) assess community participation in disaster recovery, (3) compare pre-event and current perceived resilience of landslides, (4) evaluate heritage recovery, housing recovery, and the difference between urban and rural areas, and (5) assess Build Back Better in the context of schools, residential and historic buildings.

The mission focused on the same locations visited in 2015, with the exception of the remote mountain communities near the epicentre and with additional site visits along the Ariniko Highway

to the NE of Kathmandu (Figure 2). In addition to the field visits, a range of workshops were undertaken in Kathmandu with key stakeholders.

This paper presents some of the initial findings of the 2022 return mission, focused on the Social Media and Expert Perception on Earthquake Recovery, recovery and reconstruction efforts of school infrastructure, and recovery and reconstruction of critical infrastructure to investigate the Build Back Better approach.

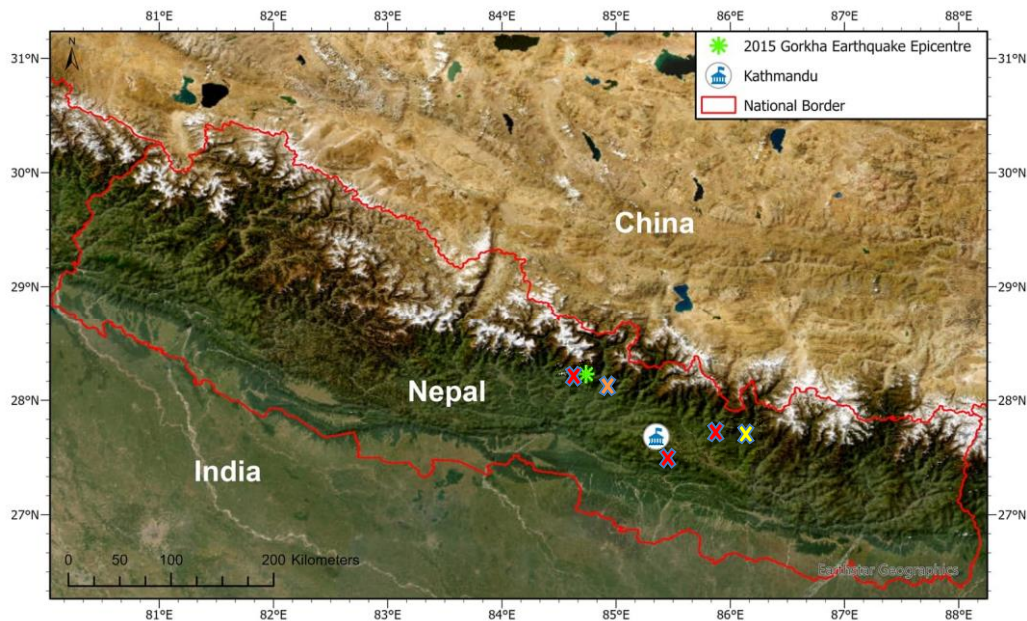


Figure 2. Nepal Location plan showing locations visited in both 2015 and 2022 mission (red), 2015 mission only (orange) and 2022 return mission only (yellow).

### Social Media and Expert Perception on Earthquake Recovery

Following an earthquake, the focus is typically on the rescue and early recovery (Figure 1), with limited assessments of the longer term recovery and development phases (Ogie *et al.*, 2022). This influences our understanding of the impact of earthquakes over the longer term. The 2022 Nepal EEFIT return mission provided a unique opportunity to evaluate the perception of long-term recovery following the 2015 Gorkha Earthquake. The approach to evaluate perception of long-term recovery was two fold: firstly using Social Media to undertake a Sentiment Analysis of tweets around the 5 year anniversary of the earthquake (Contreras, *et al* 2022), and secondly utilising the UNISDR Disaster Resilience Scorecard (UNISDR 201 ,Whitworth *et al* 2020) to evaluate expert perception to changes in resilience over the period 2015-2022.

#### Social Media Assessment

To evaluate Nepal's recovery progress, text data posted on Twitter and Instagram from March 5<sup>th</sup> to May 2<sup>nd</sup>, 2020 was evaluated based on the approach detailed in Contreras, *et al* (2022). Hashtags were used to identify in tweets related to the anniversary. The hashtags included: #Nepal, #earthquake, #Nepalearthquake, #NepalQuake, #5yearson, and #Nepali. In total over 180,000 tweets mentioned these key terms. The number of tweets containing the hashtags mentioned before and the activity on Twitter during the observation period with those hashtags is plotted on Figure 3.

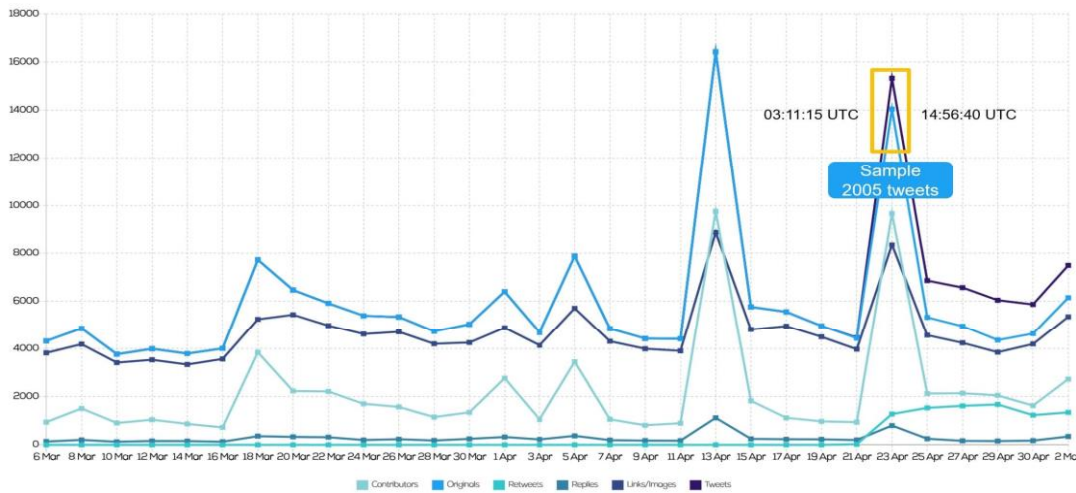


Figure 3. Twitter activity from March 5<sup>th</sup> to May 2<sup>nd</sup>, 2020. Adapted from: TweetBinder.

Social media users post online, providing text data, including emoticons expressing their opinions, thoughts or sentiments during the anniversary of earthquakes. This Sentiment can be analysed through Sentiment Analysis (SA), to evaluate the users perception of a variety of topics. Figure 4 presents the results of this analysis for the complete tweet and individual sentences within a tweet, grouping the sentiment in to broadly positive, neutral and broadly negative.

Based on the results of the SA in general and the particular topic of recovery, we could state that the recovery process is positive in Nepal, or at least the opinion of Twitter users about it is positive.

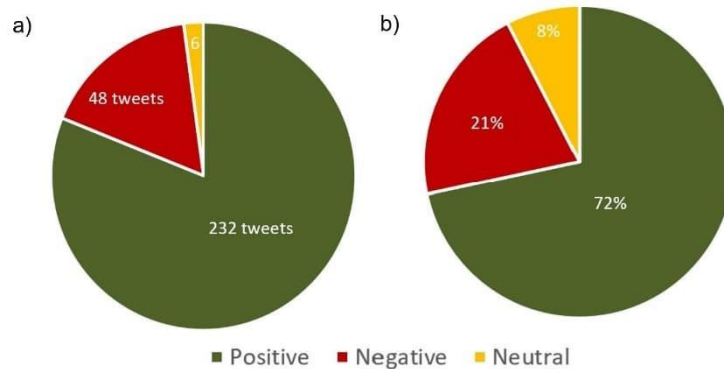


Figure 4. Sentiment Analysis (SA) of the topic of recovery (a) at tweet level and (b) at tweet and sentence level.

### Expert Perception

As part of the 2022 EEFIT return mission to Nepal a workshop was held with key stakeholders across a range of sectors involved in the earthquake recovery. During this workshop the stakeholders were engaged to complete an anonymous survey, based on the UNISDR Resilience Scorecard (UNISDR 2019, Whitworth et al 2020) to rate their perception and understanding of the earthquake recovery process. The aim of the assessment was to evaluate the change in resilience over time focused on earthquake hazard as a way to understand and evaluate earthquake recovery. The individual is asked a series of questions (Figure 5) and provides a rank to give an indicative measure against that subject. The score is indicative of the assessed resilience: the lower the score, the lower the assessed resilience. The individual was requested to provide a score for earthquake hazard for 2015, 2020 and 2022, and compare to other hazards

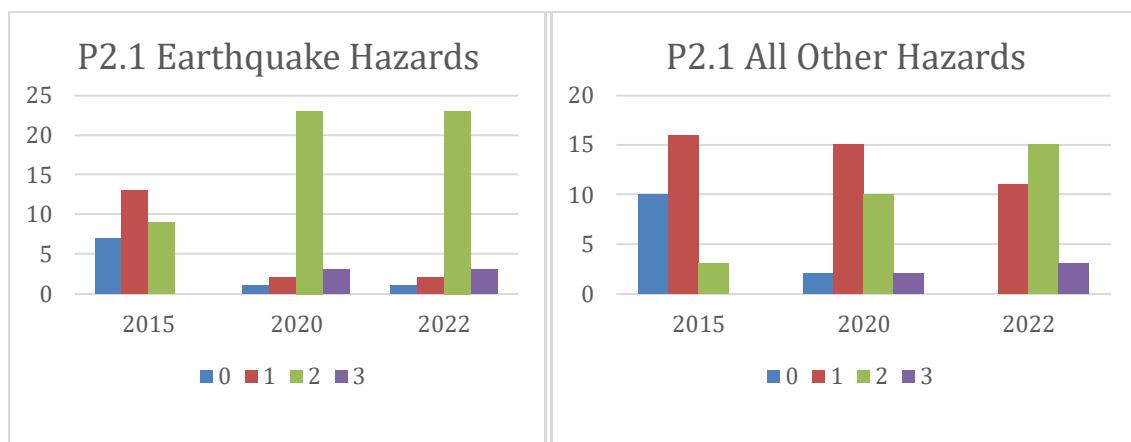
i.e. landslides, and floods for the same periods. This approach not only evaluates the general trend of earthquake recovery, but also, as the pandemic hit close to the 5 year anniversary, the change during the COVID-19 pandemic. This paper presents the findings for 2 questions related to Essential 2 “Identify, Understand and Use Current and Future Risk Scenarios”. The two questions are shown in Figure 5 and the results presented in Figure 6.

Previous assessments of resilience in Nepal immediately after the earthquake (Whitworth *et al.*, 2020 & Francis and Whitworth 2019), indicated a low resilience to earthquake hazard, with an average score of 1 in relation to Essential 2 of the UNISDR Scorecard (UNISDR 2017).

In relation to the question “Does the city have knowledge of the key hazards?”, it can be seen that in 2015 there was an even spread of 0-2, with an average of 1 for earthquake hazard. This improved between 2015-2022, showing improved resilience, but remains stagnant between 2020-2022. A similar trend was observed for earthquake hazard for P2.5. For both questions 2.1 and 2.5 only a few respondents gave a score of 3, indicating there is still further work to be undertaken to identify, understand and use current and future risk scenarios. When comparing this to all hazards across both questions, there again is an improvement in assessed resilience, although overall the change is not as pronounced. This is possibly indicative of the focus over this period on the earthquake hazard.

Ref	Subject / Issue	Question / Assessment Area	Indicative measurement scale
P 2.1	Hazard assessment	Does the city have knowledge of the key hazards that the city faces, and their likelihood of occurrence?	3 – City understands main hazards. Hazards data is updated at agreed intervals. 2 – City understands main hazards, but there are no agreed plans for updating this information. 1 – Data exists on most of the main hazards. 0 – Hazards are not well understood.
P 2.5	Presentation and update process for risk information	Do clear hazard maps and data on risk exist? Are these regularly updated?	3 – High quality hazard maps exist, for most hazards, and are regularly updated (at agreed intervals). 2 – Hazard maps exist, for most hazards, update plans are not known. 1 – Hazard maps exist for some hazards. 0 – No hazard maps exist.

Figure 5. UNISDR Essential 2 Questions evaluated as part of the stakeholder workshop.



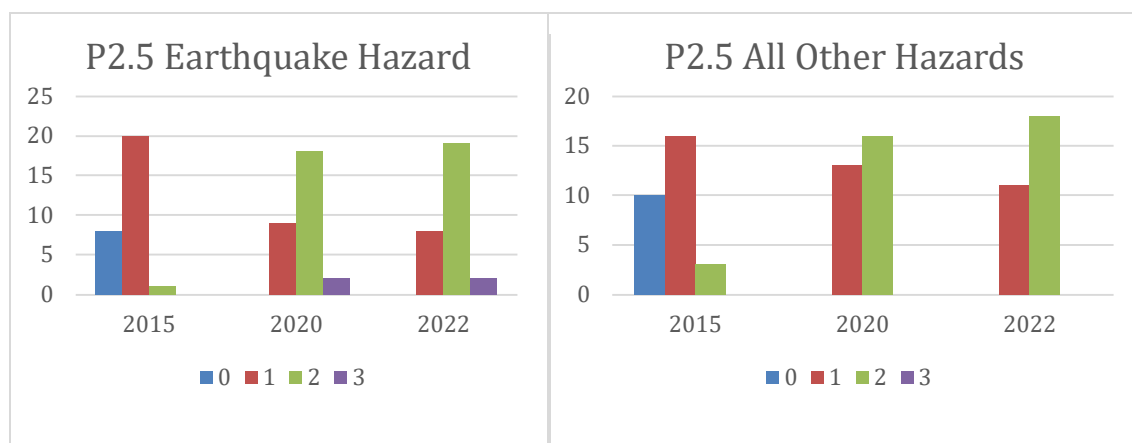


Figure 6. Results from Stakeholder Engagement for Essential 2.1 and 2.5 questions, for earthquake hazard and all other hazards.

### Recovery and Reconstruction Effort on School Infrastructure

The 2015 Gorkha Earthquake caused the collapse or significant damage of over 7,000 schools, with over one million children affected. The estimated cost of damage and recovery to the education sector is \$415 million. The immediate impact of the earthquake was the closure of schools for several months and the unavailability of schools as a secondary post-disaster facility i.e. aid distribution and communication. Long term impacts included psychological effects, lack of classrooms, the use of makeshift temporary facilities, and poor water, sanitation and hygiene facilities.

School reconstruction was a priority for the national reconstruction and recovery programme and attracted significant financial and technical assistance from international donors. An example is the 'Disaster Resilience of Schools Project (DSRP)' funded by the Asian Development Bank (ADB) which includes the retrofit of approximately 140 schools. At the time of the return mission in May 2022, the school reconstruction programme was almost complete and the retrofit programme was ongoing.

Schools were a focus for both the 2015 EEFIT mission and the return mission in 2022. Eleven schools were surveyed in 2022 including the six visited in the 2015 mission. The schools visited were a mix of rural and urban comprising both reconstructions, retrofit or a combination of both. The surveys included structural observations on the construction type, detailing and seismic vulnerabilities as well as anecdotal information on the construction programme and use of temporary accommodation. Relevant codes, standards and guidance were assessed to identify best practice and lessons to be learnt.

While most of the pre-earthquake school buildings belonged to masonry typology, almost all of the schools surveyed had newly constructed multi-storey RC buildings (Figure 7) with masonry infill which appeared to be constructed in accordance with the latest National Building Code of Nepal. Construction quality observed on school sites was equivalent to international best practice with supervisors and resident engineers providing quality control. However, by applying checklists such as FEMA P-154 rapid visual screening, some existing/added seismic vulnerabilities were identified in few cases such as:

- Foundations and ground engineering: Many schools have been built close to steep slopes and it is unclear if slope stability has been considered. Landslides and subsidence were a major issue with 2015 earthquake.
- Seismic joints and pounding: Not included in all locations with major shortcomings on some sites where floors do not align.
- Falling hazards: Water tanks with limited support were observed on top of buildings in some locations.

- Poor structural health condition and maintenance issue of buildings: Water ingress and corrosion was observed in some locations which will degrade the structural capacity and seismic resistance.
- Asymmetric masonry infill: Infill not always surrounded by RC frame.

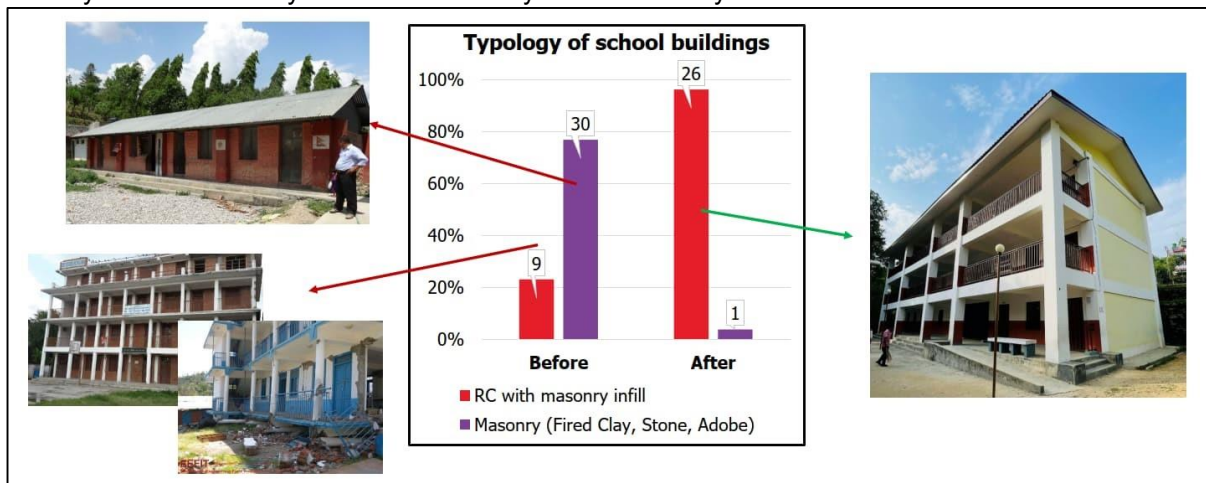
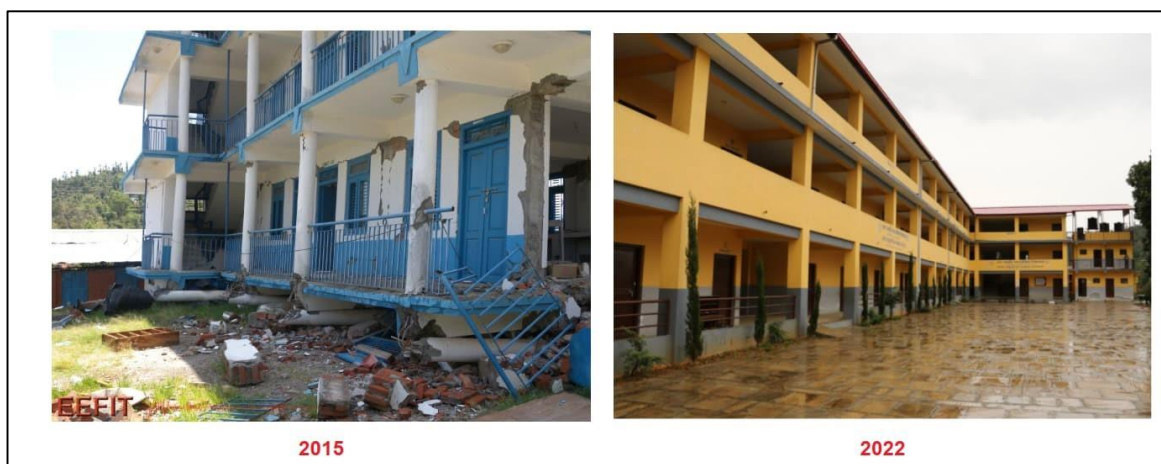


Figure 7. Distribution of the pre- and post-earthquake typologies of school buildings along with typical photographs.

Half of the schools visited had at least one existing building that was retrofitted, which is a commendable effort towards sustainable recovery process. The most common retrofit methods were column jacketing for RC buildings and RC splint and bandage or wall jacketing for masonry buildings. Some retrofitting works were ongoing at the time of the return mission and the approach appeared to be in accordance with the best practice guidance that was developed following the earthquake. Resident engineers had a good awareness of the construction quality issues and had received specialist training and support.

Lack of manuals for reconstruction and retrofit at the time of the earthquake has been cited as a major challenge for the recovery efforts. Significant improvements to the codes and guidance have been made which will improve the situation in future disastrous events. However, these still rely heavily on typical detailing rules and require the use of international codes and standards for analysis and design.

Build Back Better has clearly been achieved for schools (Figure 8) with a significant improvement in the seismic design and detailing, construction quality, number of classrooms and water, sanitation and hygiene (WASH) facilities. However, it is noted that the education sector was a priority and is likely to have received the most support.



*Figure 8. Poorly designed RC building damaged by the 2015 earthquake sequence (left) and a newly constructed RC building in the same school compound.*

### **Recovery and Reconstruction of Critical Infrastructure**

Landslides pose a particularly significant hazard, with more than 24,000 landslides triggered by the 2015 Gorkha earthquake and hundreds of landslides triggered annually by monsoonal rainfall. Although not originally visited in the 2015 EEFIT mission, the earthquake induced landslides as well as monsoons triggered landslides and their impact on critical infrastructure along the Ariniko highway has been ongoing in Nepal since the Gorkha earthquake (Jones *et al* 2021).

As part of the 2022 EEFIT return mission, site reconnaissance was undertaken along the Ariniko highway to evaluate the recovery of the landscape to earthquake induced landslides and to investigate the recovery and reconstruction of critical infrastructure to a range of geological and meteorological hazards.

Initial field observations were undertaken in 2016, 2018, 2019 (Whitworth *et al* 2020; Jones *et al* 2021a), with subsequent field visits undertaken in 2022 to evaluate the resilience and recovery of the infrastructure to these landslide events. The subsequent field visits identified that the landscape appeared to be recovering from the earthquake induced landslides (Figure 9), with little evidence of continued reactivation, confirming the findings of Jones *et al* (2021). Although aspects of the road infrastructure was repaired in 2018, this had been further damaged in 2022 (Figure 10). Hydropower infrastructure impacted by the earthquake, has now been repaired. Although the border and highway had reopened to a low volume of traffic and along the corridor there appeared an increase in economic activity, the critical infrastructure continues to be impacted by landslides, with previous mitigation measures having minimal impact.



*Figure 9. Example of revegetated earthquake-induced landslides following the Nepal 2015 earthquake, mapped in 2019 and 2022.*



Figure 10. The recovery of road and hydropower infrastructure along the Ariniko highway, left 2017, right 2022.

## Conclusions

The paper presents the findings of an Earthquake Investigation Field Investigation Team (EEFIT) return mission to Nepal in 2022. Through a range of approaches including stakeholder workshops, stakeholder questionnaires, social media studies, ludic activities, remote sensing, landslide reconnaissance and revisiting field locations from the 2015 EEFIT Mission, the team aimed to investigate the earthquake recovery and reconstruction and evaluate whether Nepal had built back better.

Social media assessment identified that a perception of users state that the recovery process is positive in Nepal, a finding reinforced by the resilience scorecard assessment undertaken with key stakeholders. The mission identified: (a) the landscape recovery from earthquake induced landslides with limited evidence of reactivation, (b) clear evidence of improved standards of school reconstruction, (c) the implementation of improved design codes and (d) an increase in a skilled work force. Despite this, seismic vulnerabilities remain, as identified in the schools assessment that will need to be addressed through a variety of factors including improved building codes and standard, training and education to improve the resilience of Nepal to future shocks.

## Acknowledgement

The author's would like to acknowledge the industry partners who supported the attendees including AECOM and Arup. Twitter's data acquisition was funded with the starting-up fund (AJ2200IN01) provided by Cardiff University to the first author. The return mission to Nepal was organised by the Earthquake Engineering Field Investigation Team (EEFIT) and funded by the Engineering and Physical Sciences Research Council (EPSRC) (Grant No.: EP/P025641/1).

## References

- J. N. Jones., S. J. Boulton., G. L. Bennett., M. Stokes., & M. R. Z. Whitworth., 2021, 30-year record of Himalaya mass-wasting reveals landscape perturbations by extreme events, *Nature Communications*, 12, 6701 (2021), <https://doi.org/10.1038/s41467-021-26964-8>
- Dini, B., Bennett, G.L., Franco, A., Whitworth, M.R., Cook, K.L., Senn, A. and Reynolds, J.M., 2021. Development of smart boulders to monitor mass movements via the Internet of Things: A pilot study in Nepal. *Earth Surface Dynamics*, 9(2), pp.295-315.
- Federal Emergency Management Agency. National Disaster Recovery Framework. 2nd ed. Washington, DC: Federal Emergency Management Agency; 2016. [https://www.fema.gov/media-librarydata/1466014998123-4bec8550930f774269e0c5968b120ba2/National\\_Disaster\\_Recovery\\_Framework2nd.pdf](https://www.fema.gov/media-librarydata/1466014998123-4bec8550930f774269e0c5968b120ba2/National_Disaster_Recovery_Framework2nd.pdf).
- Francis, M., & Whitworth M R Z. (2017). Lifeline infrastructure & the UN disaster resilience scorecard. Lowland Technology Institute. Vol 18. issue 2.
- J. N. Jones., S. J. Boulton., G. L. Bennett., M. Stokes., & M. R. Z. Whitworth., 2021a, 30-year record of Himalaya mass-wasting reveals landscape perturbations by extreme events, *Nature Communications*, 12, 6701 (2021), <https://doi.org/10.1038/s41467-021-26964-8>
- J. N. Jones., S. J. Boulton., G. L. Bennett., M. Stokes., & M. R. Z. Whitworth., 2021b, Temporal variations in landslide distributions following extreme events: implications for landslide susceptibility modelling, *Journal of Geophysical Research Earth Surface*, vol 126, issue 12, [doi.org/10.1029/2021JF006067](https://doi.org/10.1029/2021JF006067).
- M. R. Z. Whitworth, S. J. Boulton, J. N. Jones, (2020), Implementing the Sendai Framework in developing countries using remote sensing techniques for the evaluation of natural hazards, *Lowland Technology International*, vol 22 (1), pp 113 – 133.
- Whitworth, M.R.Z., Moore, A., Francis, M., Hubbard, S. and Manandhar, S., (2020). Building a More Resilient Nepal-The Utilisation of the Resilience Scorecard for Kathmandu, Nepal following the Gorkha Earthquake of 2015. *Lowland Technology International* 2020; 21 (4): International Association of Lowland Technology (IALT): ISSN 1344-9656 Special Issue on: Engineering Geology and Geotechniques for Developing Countries
- Booth, E., Saito, K., & Madabhushi, G. (2010). *EEFIT mission report: The Haiti earthquake of 12 January 2010*. Retrieved from <https://www.istructe.org/IStructE/media/Public/Resources/report-eeffitportauprince-haiti-20190816.pdf>
- Contreras, D., Wilkinson, S., Alterman, E., & Hervás, J. (2022). Accuracy of a pre-trained sentiment analysis (SA) classification model on tweets related to emergency response and early recovery assessment: the case of 2019 Albanian earthquake. *Natural Hazards*. doi:10.1007/s11069-02205307-w
- Lubkowski, Z., D'Ayala, D., Crewe, A., Manafpour, A., Grant, D., Lloyd, T., . . . Novelli, V. (2010). *EEFIT Mission Report: The Mw 8.8 Maule, Chile Earthquake of 27th February 2010*. Retrieved from <https://www.istructe.org/IStructE/media/Public/Resources/report-eeffit-maule-chile-20190814.pdf>
- Ogie, R., Moore, A., Wickramasuriya, R., Amirghasemi, M., James, S., & Dilworth, T. (2022). Twitter data from the 2019–20 Australian bushfires reveals participatory and temporal variations in social media use for disaster recovery. *Scientific Reports*, 12(1), 16914. doi:10.1038/s41598-02221265-6
- Pomonis, A., Saito, K., Frasser, S., Chian, S. C., Goda, K., Macabuag, J., . . . Murakami, H. (2011). *EEFIT Mission report: The Mw 9.0 Tohoku Earthquake and Tsunami of 11th March 2011*. Retrieved from <https://www.istructe.org/IStructE/media/Public/Resources/report-eeffit-mission-japan20111203.pdf>
- Preventionweb. (2015). Nepal: Gorkha Earthquake 2015. Retrieved from <https://www.preventionweb.net/collections/nepal-gorkha-earthquake-2015>
- Rossetto, T., Peiris, N., Alarcon, J., So, E., Sargeant, S., Sword-Daniels, V., . . . Free, M. (2009). *EEFIT Mission report: The L'Aquila (Italy) Earthquake of 6th April 2009*. Retrieved from <https://www.istructe.org/IStructE/media/Public/Resources/report-eeffit-laquila-italy-20190816.pdf>
- Wilkinson, S., DeJong, M., Novelli, V., Burton, P., Tallet-Williams, S., Whitworth, M., . . . Datla, S. (2019). *EEFIT Report: The Mw 7.8 Gorkha, Nepal Earthquake of the 25th April 2015*. Retrieved from Newcastle upon Tyne: <https://www.istructe.org/resources/report/eeffit-mission-report-gorkhanepal/>
- Wilkinson, S., Free, M., Grant, D., Boon, D., Paganoni, S., Mason, A., . . . Haskell, J. (2011). *EEFIT Mission report: The Christchurch New Zealand Earthquake of 22 February 2011*. Retrieved from

London, UK: <https://www.istructe.org/IStructE/media/Public/Resources/report-eefit-mission-newzealand-20110601.pdf>

UNISDR, (2017). Disaster Resilience Scorecard for Cities, Preliminary Assessment. United nation Office for Disaster Risk Reduction.