Final Report
on

Resilience to
High Impact Low Occurrence (HILO) disasters:
A cross-sector comparison

The National Academy of Sciences of Sri Lanka

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Contents

https://nassl.org/resilience-to-high-impact-low-occurrence-hilo-disasters-a-cross-sector-comparison/

1. Introduction

With 2024 being the 20th anniversary of the Indian Ocean tsunami and the 5th anniversary of the Covid-19 pandemic, a particular cross-cutting concern is whether our complex societies are resilient against High Impact Low Occurrence (HILO) disasters. The National Academy of Sciences of Sri Lanka (NASSL) proposed to the Association of Academies and Societies of Science in Asia (AASSA) that project be undertaken, with funding from the Inter Academy Partnership (IAP) on the topic "Resilience to High Impact Low Occurrence (HILO) disasters: A cross-sector comparison". The objective was to arrive at cross-sector strategies for such events, by drawing on the context-based expertise of some partner academies. This was expected to build the capacity of academies and also promote their collaboration and networking on issues of global, regional, and national importance. The proposal was accepted by AASSA and IAP for funding, and implemented from December 2023 (planning) to November 2024 (final deliverables).

The methodology involved (i) the design of a template to capture cross-cutting features of HILO events; (ii) populating the template using a range of HILO events by a set of partner academies; (iii) a physical meeting in Colombo to arrive at cross-sector best practices; and (iv) dissemination via a report and other strategic modes of communication. The outcomes were expected to empower academies and regional academy networks to provide independent, authoritative advice to governments.

The deliverables of the project were to be:

(i) A list of partner academies and their nominees to study HILO events
(ii) A template to gather information from the above nominees on various aspects of these events
(iii) A desk review of HILO events in the AASSA region, based on the above completed templates
(iv) A physical meeting of partner academy nominees in Colombo, Sri Lanka, together with other selected experts and participants from government and non-government agencies; engaging also with young academicians and young physician leaders
(v) A final report, including the actual meeting report and best practices arrived at by consensus
(vi) A journal paper for archival impact
(vii) A short video for impactful dissemination

2. Methodology

All AASSA members and even others (e.g. from Australia) were invited to participate in this study, with appropriate HILO disasters to analyse. However, only the six academies listed in Table 1, (together with their chosen nominees and HILO disasters) were able to participate. The Ajerbaijan National Academy of Sciences indicated a willingness to participate, but were not able to collaborate. The GDP column serves as an indication of socio-economic status, since that was also expected to be a key parameter, in addition to the types of disasters. It is clear that Japan stands out from the rest; and this was borne out in the subsequent analysis as well. Two of the disasters are biological ones (both related to Covid-19, i.e. in Indonesia and Nepal), while two are natural ones (i.e. the flood in India and the tsunami in Sri Lanka). The Japanese disaster is a technological one (Fukushima), but precipitated by a natural disaster (i.e. a tsunami). Finally, the refugee problem in Bangladesh can be considered a sociological disaster. This spread of HILO disaster types constituted a rich data set for analysis.

Table 1 – Partner Academies and their HILO disasters

Academy	Fellow	HILO disaster	GDP (PPP) - USD
Science Council of Japan	Prof Kenji Satake	2011 Tohoku earthquake, tsunami; plus Fukushima	41,838
Bangladesh Academy of Sciences	Dr. Kazi Matin Uddin Ahmed	Rohingya refugees influx into Cox's Bazaar	6,263
Nepal Academy of Science and Technology	Prof Anjana Singh	Covid 19 pandemic in Nepal	4,002
Indian National Science Academy	Dr. Kalachand Sain	2013 Kedarnath Glacier Lake Outburst Flood	7,112
Indonesian Academy of Sciences	Dr Finarya Legoh	Covid 19 from AIPI perspective	12,410
National Academy of Sciences of Sri Lanka	Prof. Priyan Dias	2004 tsunami	12,200

The research team was led by Professor Priyan Dias from the NASSL. It was decided to invite Professor Udayangani Kulatunga (University of Moratuwa; disaster management specialist)) and Dr Unnathi Samaraweera (University of Colombo; sociologist) to form the core research team with Professor Dias. Regular online meetings were held in order to steer this project, with inputs from Prof Nadira Karunaweera (Past President NASSL) and Prof Ajit Abeysekera (President NASSL).

The first output from the research team was the template for the case studies – see Annex 1. This template was also shared with nominees of partner academies (Table 1) and finalized via online discussions. The nominees provided valuable inputs and additions to the template.

The next stage was to collect the filled templates for the six different HILO disasters. They were filled once again by the Fellows indicated in Table 1. Once this was done, the analysis was carried out by Dr Samaraweera, under the guidance of Professor Kulatunga, with overall supervision from Professor Dias. The resulting analysis (or desk review) is presented in Annex 2.

The next stage in the process was the physical workshop, involving the fellows from all participating academies and others, held in Colombo, Sri Lanka from 5-7 September 2024. The report of the workshop is presented in Section 3.

After the workshop, a journal paper was prepared by the core research team to capture the process and findings. In addition, Mr Yohan Abeynaike, who had done similar work for NASSL before,

was recruited to produce a short 10 minute video summary of the workshop and its findings. The script for this video is included as Annex 6.

2.1. NASSL Engagements

During the entire project, NASSL was sensitive to AASSA/IAP concerns regarding the engagements that were undertaken as a background to the actual work carried out.

First, there were representatives from both the Sri Lanka Association of Young Scientists (SLAYS) and the community of IAP Young Physician Leaders (YPL). We have engaged with these two bodies through the past years and have developed good working relationships with them. In fact, during the workshop, it was tentatively agreed that the YPL community would get formalized to an extent, at least by the appointment of a coordinator.

Second, the timing of the event coincided with national and global events surrounding the 2004 Indian Ocean Tsunami in particular. For example, the Disaster Management Centre (DMC) of Sri Lanka had an international technical symposium on 4 November 2024 (the day before World Tsunami Awareness Day) on the topic "Reflections on two decades from tragedy to resilience: Retrospect of the 2004 Indian Ocean Tsunami". This was supported by the UN agencies United Nations Development Program (UNDP), United Nations Children's Fund (UNICEF) and International Organization for Migration (IOM). Professor Priyan Dias (Fellow NASSL and main organizer for the HILO workshop) was invited as the keynote speaker, and was able to share some insights gained from the NASSL workshop regarding best practices for increasing resilience against HILO disasters such as tsunamis. Furthermore, he was interviewed for a video documentary (to be released in December 2024) on the topic of the DMC technical symposium.

Third, some of the partners academies who participated in our project did so for the first time – in particular the Science Council of Japan (SCJ) and the Indian National Science Academy (INSA). The Azerbaijan National Academy of Sciences (ANAS), a relatively new academy in the IAP family, took part in the initial online discussions, but were unable to either fill a template or attend the workshop. Every attempt was made to engage an expert from the Australian Academy of Engineering and Technology (which is an academy outside of IAP/AASSA), but this partnership did not materialize, mainly due to the non-availability of the HILO disaster expert, Professor Mark Stewart. It is expected however, to disseminate our findings to Prof. Stewart and engage with him and his academy in the future.

3. Workshop Report

The workshop agenda is given in Annex 3; the event lasted from the evening of Thursday 5 September to lunch on Saturday 7 September 2024. The participant list in Annex 4 includes all participants we engaged with, though not all were physically present – details of those actually attending in person are also given in Annex 4. Others may have joined via the zoom link circulated. At any rate, all dissemination material will be sent to all listed in Annex 4, in addition to others.

The agenda comprised (i) keynote talks; (ii) partner presentations on their HILO events; and (iii) participant discussions and feedback. The opening ceremony on the evening of 5 September features welcome addresses from Prof. Ajit Abeysekera, President NASSL and Prof. Nuri Yurdusev, President AASSA; a message (via zoom) from Dr Peter McGrath, coordinator IAP and a guest speech by Dr Ananda Mallawatantri, an advisor to H.E. the President of Sri Lanka. A special guest at this ceremony was H.E. Semih Turgut, the Turkish Ambassador to Sri Lanka.

The key feature of the evening of 5 September was a keynote address delivered via a zoom link by Dr Sonali Deraniyagala, attached to the Department of Economics at the School of Oriental and African Studies (SOAS) of the University of London. She spoke on the topic "Economic Impacts of High Impact Low Occurrence (HILO) disasters". In her talk she sought to answer three questions, namely (i) Are disasters entirely natural? (pointing out that disasters occur because people are forced to live in areas that are highly exposed to hazards); (ii) How do disasters affect economic development? (describing how the macroeconomic indicators such as GDP of even poor countries return to trend a few years after major disasters; but how those who fall into poverty after disasters remain there even for multiple generations); and (iii) What are the challenges to economic recovery? (where she promoted measures such as cash transfers and livelihood projects for the poor; while suggesting that national solutions such as increased taxation of non-affected regions may be better than foreign aid which may not get utilized well). She also explained that the poor are affected more by disasters because (i) they are more exposed geographically; (ii) they are in rural areas, whose economies are more affected by climatological disasters such as flood and drought; (iii) their assets are of inferior quality (inclusive of minimal savings in banks); (iv) they are employed in the informal sector, which is much worse affected by disasters; and (v) they are more affected by spikes in food prices.

The morning of 6 September saw three keynote talks. The first was by Prof. Dilanthi Amaratunga, Professor of Disaster Risk Reduction and Management at the Global Disaster Resilience Centre of the University of Huddersfield in the UK. She presented a "Comparison between Natural HILO hazard (Tsunami) and Biological HILO hazard (Covid)". While comparing the effects of natural and biological disasters, she also talked about being prepared for the simultaneous occurrence of a natural and biological disaster. She highlighted the complexity of our societies (e.g. supply chains) and its implications for cascading effects of disasters. She also emphasized aspects such as preparedness, planning, coordination and care of frontline workers. Two instruments she described were the development of Standard Operating Procedures (SOPs) and drills, one of which, the Indian Ocean Wave (IOWave) exercise is carried out every 2-3 years, giving opportunities to test (and improve) the effectiveness and efficiency of aspects ranging from technological early warning systems to sociological last mile evacuation responses.

The next keynote talk on the morning of 6 September was by Dr Senaka Basnayake, Director, Climate Resilience, Asian Disaster Preparedness Center (ADPC), who spoke on "Disaster Management and Mitigation in Asia". He emphasized again that disasters are caused only when humans are exposed to natural hazards, defining risk as a combination of hazard, exposure and vulnerability. After giving examples of some HILO disasters, he spoke about some of the key global and regional agreements relating to climate phenomena (e.g. Sustainable Development Goals – SDGs); and then about ADPC's role and interventions in the Asian region, focusing again on drought and flood. He made the point that HILO disasters fail to attract the funding required to increase preparedness and mentioned some funding mechanisms. He addressed early warning systems too, emphasizing that the warnings should highlight impacts and not merely numerical estimates of weather parameters – in other words to describe not merely "what the weather will be" but also "what the weather will do". Finally he discussed the modelling of climate change phenomena and their impacts.

The final keynote talk for the morning of 6 September was by Prof. Udayangani Kulatunga, Professor in Building Economics at the University of Moratuwa, Sri Lanka. She presented a "Cross sector comparison of HILO disasters based on country", which was a summary of the pre-workshop analysis of the partner HILO templates on different disasters (see Table 1), the full description of which can be found as Annex 2. She presented the methodology of the NASSL study, and also outlined the differences between natural, biological, technological and sociological disasters; while also pointing out that the national context also played a role the overall unfolding of a disaster. She covered aspects such as Preparedness (pre-disaster phase), Response (disaster phase) and Recovery (post-disaster phase). Especially where recovery was concerned, she dealt with parameters such as inequity and governance (whether centralized or decentralized). The factors influencing recovery were identified as Economic, Social Capital and Religious/Cultural Factors. She also suggested Structural, Social and Economic measures for investments towards mitigation; arguing that such investments would have benefits even for everyday life.

The afternoon of 6 September was allocated to the presentations on the six HILO disasters listed in Table 1. The contents of these presentations are based on the templates filled by the nominees of each partner Academy (Table 1). These contents are captured in comparative form in the pre-workshop comparative analysis report found in Annex 2.

The last session of the workshop was on the morning of 7 September, when the participants, including partners, experts and Sri Lankan invitees, discussed in groups and presented their feedback on three questions posed to them, i.e. (i) What categories should we employ in the analysis of HILO disasters?; (ii) What are the lessons that have been learnt through the analysis of HILO disasters?; and (iii) What strategies can be used for resilience against HILO disasters? The collated responses from all four groups are presented as Annex 5.

4. Journal Paper

DRAFT

Target Journal: *International Journal of Disaster Risk Reduction (IJDRR)*

A Cross-Sector Analysis of High Impact Low Occurrence (HILO) Disasters

Authors: Unnathi Samaraweera, Udayangani Kulatunga, Priyan Dias

1. Introduction

In the recent decades, the risk landscape has significantly changed with new and emerging risks. The 'risk magnifiers' for instance, infectious diseases, climate change and environmental degradation, cyber-attacks, terrorism have laid an additional layer of risk to communities globally to anticipate and prepare for unpredictable disasters (United Nations Office for Disaster Risk Reduction (UNDRR), 2023).

High-impact, low-occurrence disasters are events that, while rare, have the potential for significant damage and disruption when they do occur (Fujita and Yamashiki, 2022). They are often unpredictable, difficult to imagine and can overwhelm communities or systems that aren't adequately prepared (Blackett Review of High Impact Low Probability Risks, 2011). HILO disasters often surpass the coping capacity of the communities affected, hence it is often stated that such events need to be given more prominence than what the statistics imply (Merz, Elmer, and Thieken, 2009). HILO disasters include disasters such as large earthquakes, tsunami, nuclear power plant failures, volcanic eruptions, pandemics etc. These disasters often require extensive preparation and mitigation efforts due to their potential severity, even though they may not occur frequently.

HILO disasters can be broadly divided into disasters triggered by natural hazards (such as tsunami, earthquakes), biological events (pandemics), technical and industrial events (nuclear powerplant failures), socio- political events (major conflicts, economic crisis), environmental events (collapse of major ecosystems), human caused disasters such as terrorists attacks.

Each of these categories involves events with the potential for severe consequences, even though their likelihood of occurrence is relatively low. For example, the Indian Ocean Tsunami caused extensive damages to property and losses to human lives (ADB, 2005). Further, the Fukushima nuclear power station incident caused significant within and cross border impacts (The National Diet of Japan 2012). Despite their low occurrence, statistics indicate that the extensive losses and damages caused by HILO disasters are much more than the regular disasters (Wolbers, Kuipers and Boin, 2021). Especially, when comparing the human lives lost, the HILO disasters indicate extensive losses when compared with the other regular disasters. The challenge with the HILO disasters is their unpredictability and the potentially devastating impacts that they cause.

The main characteristic of HILO disasters is their low occurrence coupled with the high impact. These types of disasters are unpredictable and fall outside the normal expectations based on historical data. Without frequent occurrences or reliable historical patterns, forecasting such disasters becomes nearly impossible (Fujita and Yamashiki, 2022). Risk assessments often rely on historical patterns, but for HILO events, the lack of frequent data points results in an incomplete understanding of potential risks and impacts. Therefore, it is difficult to anticipate and plan for them. Even if a potential risk is known (like earthquakes or pandemics), predicting the exact magnitude or range of impacts can be highly uncertain. Further, the cascading impacts that could get triggered from HILO events also difficult to predict and prepared for. This unpredictability makes it hard to assess the full extent of preparedness measures needed.

Further, due to their low probability, they often receive less attention and resources in disaster risk management planning (Etkin, Mamuji, and Clarke. 2018). Decision-makers may not prioritize them, as the opportunity cost of preparing for a rare event might seem too high compared to immediate, compelling needs. Furthermore, investing significant resources into preparing for events that may never occur could be often seen as inefficient (Fujita and Yamashiki, 2022). This results in insufficient funding for HILO disaster preparedness and mitigation strategies. Further, even if a plan is created, maintaining readiness over long periods of years or decades without the disaster actually occurring can

be difficult to justify and costly. Equipment can become outdated, skills can deteriorate, and people may grow less worried over time regarding such HILO disasters.

From the risk perception perspective of the people, HILO disasters attract less attention due to their less frequency and visibility. Therefore, even from individual perspectives, communities are less motivated to plan and invest in preparing for them. For example, high frequency disasters generally get more attention and periodic review of the disaster risk reduction measures. However, less preparedness and less resource allocation makes the impacts of HILO disasters even more devastating when they do occur.

Preparing for HILO disasters requires extensive and comprehensive planning, involving scenarios that may not be fully imagined. For example, planning for a pandemic would involve healthcare systems, economic measures, global supply chains, and public communication strategies. Further, since HILO disasters are rare, it's hard to test preparedness plans in real-world situations. Simulations may not fully capture the chaotic and large-scale nature of such disasters, leading to unforeseen gaps in readiness when the event occurs.

Fujita and Yamashiki (2022) argue that it is essential to find appropriate mechanisms to compensate for the damages and losses created due to HILOs to increase the preparedness for them. Etkin, Mamuji, and Clarke (2018) too state that adequate preparation for rare disasters is important so that insufficient attention to mitigation and prevention strategies can be avoided. Further, Mamuji and Etkin (2019) argue that similarity assumed for low-probability/high-consequence events and high probability/low-consequence events in the risk matrices are misleading, hence rare disasters should be analysed based on a systems perspective and should be given more importance as the lack of preparedness for such events could elevate the impacts.

The main aims of this paper are first to analyse a set of HILO disasters across different sectors (i.e. natural, technological, biological and sociological), based on responses to a standardised template, using the pre-disaster, disaster response and post-disaster recovery phases as the main categories of analysis; and also that of mitigation and prevention. The

discussion then considers aspects such as socio-economic context, governance and equity across these phases, leading to conclusions in the form of lessons learnt and strategies for resilience.

2. Methodology

This research paper employs a robust methodological framework to investigate High-Impact Low-Probability (HILO) disaster events. A standardized template comprising 21 key questions covering pre, during and post disaster phases pertinent to HILO disasters that were prevalent in the literature was administered to six country experts, facilitating the collection of comprehensive data regarding the specific disasters examined in this study. Adopting a qualitative research approach, the responses from the experts were initially entered into an Excel spreadsheet for systematic organization. Subsequent analysis was conducted using a summative content analysis method, which is characterized by its methodological rigor.

Qualitative analysis encompasses a systematic process of reduction, while summative content analysis aims to identify significant components within the text and evaluate its overall implications. Within this framework, the term "essential text" refers to elements within the data that illuminate the overarching meaning and significance of the findings. Essential text components may include contextual information, personal experiences, and emotional narratives, as outlined by Rapport (2010).

In the examination of the HILO disaster data, the study first generated codes, which were subsequently developed into relevant themes and sub-themes. This thematic analysis involved a meticulous comparison of similarities, differences, and lessons learned from each disaster, allowing for a comprehensive understanding of the phenomena under investigation.

Preliminary findings were presented at a three-day HILO workshop that convened approximately 40 disaster-related country experts and stakeholders. A dedicated session during the workshop facilitated small group discussions, enabling participants to generate insights categorized into three areas: analytical categories, lessons learned from the events,

and strategies for resilience. This paper ultimately emerges from the synthesis of both the template analysis and the collaborative discussions conducted during the workshop. In addition, some insights were gleaned from the keynote speakers at the HILO workshop as well.

3. Country specific HILO disasters

This section provides an overview of six country-specific High-Impact, Low-Probability (HILO) disasters selected for this study – see also Table 1. Note that the inputs for the analysis were provided by representatives of the six academies of science indicated, under the auspices of the Association of Academies and Societies of Science in Asia (AASSA), with coordination carried out by the National Academy of Sciences of Sri Lanka (NASSL). The table also gives the GDP (on a PPP basis) for the countries concerned, and highlights the variety of HILO disaster types covered.

Table 1: The six HILO disasters considered

Academy	HILO disaster	Type	GDP (PPP) - USD
Science Council of Japan	2011 Tohoku earthquake, tsunami; plus Fukushima	technological	41,838
Bangladesh Academy of Sciences	Rohingya refugees influx into Cox's Bazaar	sociological	6,263
Nepal Academy of Science and Technology	Covid 19 pandemic in Nepal	biological	4,002
Indian National Science Academy	2013 Kedarnath Glacier Lake Outburst Flood	natural	7,112
Indonesian Academy of Sciences	Covid 19 from AIPI perspective	biological	12,410
National Academy of Sciences of Sri Lanka	2004 tsunami in Sri Lanka	natural	12,200

The first case study is the Indian Ocean tsunami of 2004 in Sri Lanka. This catastrophic event occurred on December 26, 2004, and impacted numerous countries surrounding the Indian Ocean, with Indonesia being the most severely affected, followed by Sri Lanka to a lesser yet significant extent. The tsunami was triggered by a massive submarine earthquake, which struck approximately 400 km west of northern Sumatra at around 6:30 AM Sri Lanka time. The earthquake registered a magnitude of 9.3 on the Richter Scale, with a fault length exceeding 1,000 km. The tsunami reached Sri Lanka's eastern coast at approximately 8:30 AM and its western coast by 9:30 AM, affecting over two-thirds of the

nation's 1,400 km coastline (Dias et al. 2006; Hettiarachchi and Dias, 2013; Khazai et al. 2006). The disaster resulted in the deaths of approximately 40,000 individuals and the destruction or damage of around 120,000 houses. The direct economic losses related to assets and infrastructure were estimated at nearly US$ 1.0 billion, with total losses approximating US$ 2.2 billion. The housing sector experienced the most significant asset loss, estimated between US$ 306 million and US$ 341 million (ADB, 2005).

The second case study focuses on the 2011 Great East Japan Earthquake and the Fukushima Nuclear Power Station accident. On March 11, 2011, a massive earthquake with a magnitude of 9.0 struck off the coast of Tohoku, Japan, generating a devastating tsunami. This earthquake was the largest recorded in Japanese history and the fourth largest globally. It resulted in nearly 20,000 casualties, predominantly due to the ensuing tsunamis. More significantly, the tsunami inflicted extensive damage to the Fukushima Dai-ichi Nuclear Power Station, leading to reactor meltdowns, hydrogen explosions, and the release of radioactive materials (Satake 2014; The National Diet of Japan 2012; Yano et al. 2021).

The third case study examines the Glacial Lake Outburst Floods (GLOF) that occurred in Kedarnath, Uttarakhand, India, in 2013. From June 14 to 17, 2013, intense flash floods emerged as one of the most catastrophic disasters since the 2004 Indian Ocean tsunami, posing significant challenges for rescue operations in India. The floods were precipitated by unprecedented rainfall, rapid melting of snow and glaciers in the upper reaches, and the subsequent filling and breaching of the moraine-dammed Chorabari Lake. The sudden and immense outburst of water, laden with debris and boulders, surged down the steep slopes, devastating villages such as Gauri Kund, Ram Bada, and Sonprayag in the Kedarnath region. This deluge, compounded by landslides, resulted in approximately 6,000 fatalities, with hundreds reported missing, inundated 5,500 villages, and stranded over 100,000 pilgrims and tourists during the peak summer season. According to ecologist Chandra Prakash Kala, the estimated financial losses included $285 million in damages to bridges and roads, $30 million for dam repairs, and $195 million impacting state tourism (Agarwal et al. 2022; Dobhal et al. 2013; Rautela, 2013).

The Fourth Case is the COVID-19 Pandemic in Nepal (January 2020 to October 2022). The COVID-19 pandemic, caused by the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), has had significant health and economic repercussions globally. In Nepal, the first case of COVID-19 was reported on January 24, 2020, in a student returning from China, with a subsequent case identified approximately two months later in an individual returning from France. A complete genome sequence of the SARS-CoV-2 strain from a Nepalese patient exhibited a 99.6% identity with the reference genome. Notably, a majority of reported COVID-19 cases were asymptomatic. During the early stages of the pandemic, the potential for an outbreak in Nepal was considerably underestimated; however, there was a marked increase in cases over time, highlighting the challenges faced in managing the pandemic response (Dawadi et al. 2022; NPC (National Planning Commission) Government of Nepal, 2020; WVIN (World Vision International Nepal) 2020).

The Fifth Case is the COVID-19 Pandemic in Indonesia (January 2020 to December 2022). Indonesia reported its first confirmed cases of COVID-19 at the beginning of March 2020, with two cases identified. By April, the country recorded 1,790 confirmed cases, including 113 new cases, 170 deaths, and 112 recoveries. As the threat of COVID-19 became apparent, the Indonesian government implemented various policies to address the crisis, including designating 100 domestic general hospitals as Referral Hospitals (Rumah Sakit Rujukan) in March 2020, a number that increased to 227 within a month. Nevertheless, despite these measures, the number of cases continued to rise rapidly. The Ministry of Health of Indonesia established a website to provide real-time data on the impacts of COVID-19 within the country (Prianto et al. 2023; Sunjaya et al. 2022; UNICEF et al. 2021).

The Sixth Case is the Impacts of Rohingya Refugee Influx on the Groundwater System of Cox's Bazar Region in Bangladesh and Potential for Conflicts. The influx of Rohingya refugees into Bangladesh began on August 25, 2017, following military operations by the Myanmar Army in northern Rakhine State. During the period from August to November 2017, over 750,000 forcibly displaced Myanmar nationals of Rohingya ethnicity fled to Bangladesh, joining earlier waves of Rohingya refugees who had sought asylum in the 1970s and 1990s. Currently, nearly one million Rohingya refugees reside in Bangladesh, predominantly in the

Cox's Bazar district, near the Myanmar border (Kudrat-E-Khuda 2020; Quader et al. 2021). This sudden influx has exerted immense pressure on the local host community and its already strained facilities and services. Initially, the local population extended support and assistance to the newcomers; however, over time, the host communities' immediate sympathy waned due to increasing pressure on land, forest, and groundwater resources. The arrival of Rohingya refugees has indeed strained natural resources, particularly in the Cox's Bazar region, raising concerns about potential conflicts arising from resource competition (Milton et al. 2017).

The selected HILOs encompass a range of events, including hazard-induced disasters (tsunamis, earthquakes, floods), biological disasters (Covid 19 pandemic) and, sociological disaster (refugee influxes). For instance, the Indian Ocean tsunami and the Kedarnath GLOF are classified as hazard-induced disasters resulting from geophysical processes, while the COVID-19 pandemic in Nepal and Indonesia represents a public health crisis with extensive socio-economic implications. The Rohingya refugee influx in Bangladesh exemplifies a humanitarian crisis, resulting from geopolitical conflicts and environmental factors. This diversity necessitates tailored response strategies that account for the unique characteristics and impacts of each HILO event.

4. Data analysis and findings

4.1. Preparedness: Awareness, knowledge and experience on the HILO events

The study findings suggest lack of awareness of the risk prior to HILO disaster, underestimation of disaster risks and lack of effective preparedness among the government, experts and people coupled with scale and suddenness of the disaster event leading towards high impact of such low occurrence disasters in the Asian region. In addition, disasters such as Indian Ocean tsunami, Fukushima nuclear power station accident, and the influx of Rohingya refugees were not adequately recognized as risks, primarily due to their infrequent occurrence. In Sri Lanka, for instance, there was a complete lack of awareness regarding the tsunami risk among all parties. However, Japan stood out as an

exception for its successful handling of tsunamis and nuclear power plant accidents in terms of preparedness although certain policy measures were not effectively implemented at the grassroots level, revealing gaps in implementation, particularly in the case of Japan.

A lack of effective preparedness was evident across all contexts for Indian Ocean tsunamis, Glacial Lake Outburst flooding, Covid-19 pandemic in Nepal and Indonesia, and Rohingya refugee influxes. For instance, India encountered challenges related to preparedness and rapid emergency responses during Glacial Lake Outburst Floods. Moreover, with the exception of Japan, all other countries acknowledged the need to enhance preparedness, particularly given the high-impact, low-occurrence (HILO) nature of these particular disasters. The study findings emphasized the critical significance of implementing a reliable early warning system for such HILO events. This system should cater to not only the disaster-specific needs but also address the socio-economic and cultural considerations unique to each context.

The existing science communication in all HILOs studied in this study indicated shortcomings, emphasizing the need of rapid evolution. The findings of this study underscore the necessity for well-developed early warning systems in which science communication is integral both during and after High Impact Low Occurrence (HILO) disaster events.

4.2. Responses to HILOs

The research findings indicate the diverse actions undertaken by governments during the HILO disaster phase. For instance, during the Rohingya refugee influx, the Bangladesh government permitted Rohingyas to seek refuge across the border, providing essential security, food, and emergency medical services. The study findings show across all HILO disasters, that governments established relief camps to offer shelter, sustenance, and medical aid to affected individuals as an initial emergency response to Indian Ocean tsunami, Fukushima nuclear accidents, Glacial Lake Outburst floods, and Bangladesh refugee influxes. Similarly, in response to the Covid-19 pandemic, both the Nepalese and

Indonesian governments implemented various measures such as endorsing universal personal protection, enforcing physical distancing, imposing localized lockdowns, travel restrictions, isolation protocols, and selective quarantines.

A consistent feature observed across all HILO disasters examined in this study was the active involvement of civil society in response efforts. In India, numerous civil society members played a pivotal role in delivering humanitarian aid and relief services to affected communities. Volunteers participated in rescue operations, distributed essential supplies such as food and medical assistance, and organized temporary shelters. Community groups and religious organizations effectively managed resources and extended support to impacted families, coordinating relief initiatives and addressing the immediate needs of vulnerable populations. The active engagement of civil society entities across these HILO disasters underscored their crucial role in facilitating response and recovery processes, showcasing resilience and solidarity in times of crisis.

Parallel to the responses from civil society, the general public also played a significant role across various HILO disasters. In Sri Lanka, individuals offered emergency shelter, transportation, food, and clothing to those affected by the disaster. Remarkable frontline work was carried out, with the Ministry of Health establishing a network of safe houses through local initiatives to provide affected individuals with shelter, sustenance, and accommodation. The unique response dynamic underscores the diverse approaches taken by communities in different disaster scenarios, highlighting the importance of coordinated efforts and adaptive strategies to effectively address the challenges posed by HILO disasters. One difference in the Covid HILO disasters was that civil society and the general public were both constrained and restrained in their responses, due to the contagious nature of the pandemic that afflicted those affected.

4.3. Recovery phases in HILOs

As illustrated in Table 2, all High-Impact Low-Probability (HILO) disasters not only implemented short-term recovery plans but also established long-term recovery strategies.

This is attributable to the significant impact of HILO disasters, as all affected communities continue to experience some form of recovery due to its high impact nature.

Table 2: Timescale of the event and recovery

Disaster	Date/s of the event	Time scale of the event	Time scale of the recovery
Sri Lanka :Indian Ocean tsunami 2004	26th December 2004	A matter of hours. Two waves. The time for the waves to arrive on the West coast was around an hour later than on the East coast.	**6 months** : resumption of education activities and restoration of rail and road networks, telecommunication networks. **5 years:** e.g. housing and school reconstruction. **More than 10 years**: Businesses.
Japan: The 2011 Great East Japan Earthquake Disaster and the Fukushima Nuclear Power Station Accident	11 March 2011, a giant earthquake (Magnitude 9.0) occurred off Tohoku, Japan, generating a devastating tsunami.	The tsunami damage occurred within hours of the earthquake. The radioactive release was mostly within a month of the earthquake.	The contamination continued for years. The recovery from the tsunami damage took years, and now it is almost completed. **More than 10 years**: However, the recovery from radioactive pollution still continues after more than a decade.
India: Glacial Lake Outburst Floods (GLOF) at Kedarnath temple town in 2013 (Kedarnath GLOF in 2013) in the Uttarakhand Himalaya, India	Flash floods over a few days during 14th to 17th June 2013	Immediate Event **2 days (June 16-17, 2013)**: June 16, 2013: Incessant rainfall and fast melting of Chorabari Glacier led to swelling of the Mandakini River. June 17, 2013: Rainfall, landslides and breaching of Chorabari Lake caused massive destruction in the Kedarnath town and surrounding areas.	**6 months** : Short-term response **5 years**: Median - term response (2013-2014) **More than 10 years**: Long-Term Rehabilitation (2017-Present)

Nepal: Covid 19 pandemic	January 2020 to October 2022	December 2019 till October 2022	**6 months** : Short-term response **5 years**: Recovery is still being continued, mainly to promote economic development.
Indonesia: Covid 19 pandemic	January 2020 to December 2022	January 2020 to December 2022	**6 months** : Short-term response **5 years**: Recovery is still being continued, mainly to promote economic development.
Bangladesh: Impacts of Rohingya Refugee Influx on Groundwater System of Cox's Bazar Region in Bangladesh and Potentials for Conflicts.	The main event of influx lasted for about three months. The influx began on 25 August 2017, after the Myanmar Army launched security operations in northern Rakhine state	The main event of influx lasted for about three months. In September, 2017 an average of approximately 14,500 people arrived daily. This dropped to an approximate average of 3,100 arrivals per day in October, 2017.	**6 months** : Some aspects of the recovery was completed such as setting camps, registering the refugees, providing humanitarian assistance, improvising WASH facilities, setting us Medicare facilities, setting up schools, etc. **5 years**: However, many of these along with other recovery responses, such as avoiding conflicts with local communities, reducing pressure on shared resources such as land, fuel wood and groundwater; increasing resilience to landslide etc are still ongoing.

All HILO disasters were characterised by immediate relief efforts from governments, civil society, and the unaffected general public. Nonetheless, it is noted that the return to normalcy often extended over time due to the high-impact nature of these disasters. The Indian Ocean tsunami of 2004 highlighted the effectiveness of immediate aid responses. In the context of the Fukushima Nuclear Power Station accident, long-term recovery and rebuilding efforts faced challenges in gauging the opinions and consensus of residents. In instances of Glacial Lake Outburst Floods, the efficacy of response efforts was enhanced by well-coordinated initiatives that involved government agencies, civil societies, and international partners. During the COVID-19 pandemic in Nepal, the effectiveness of

response initiatives in facilitating a return to normalcy similarly depended on an uninterrupted transition from emergency relief to long-term recovery efforts. In comparison to other epidemic and endemic conditions, the return to normalcy during the COVID-19 pandemic was protracted due to the novel nature of the disease and the absence of an established cure. Various trial methods were employed, including traditional, Ayurvedic, and allopathic approaches, to address the health crisis. In Indonesia, effective collaboration between the government and local communities demonstrated greater efficacy in response efforts. In the Rohingya refugee influx, a multi-tiered response involving government and local communities, NGOs, civil societies, and international organizations effectively provided humanitarian services to a substantial number of individuals.

In addition, analysis suggests that, in most instances, post-disaster recovery measures have contributed to the exacerbation of existing socio-economic disparities within local contexts rather than diminishing them in given post HILO disaster events. Further, this study demonstrates the active participation of the international community in disaster relief and post-recovery efforts, with the notable exception of the Rohingya refugee influx. Reports indicate that the international response was delayed in this context, primarily due to the complexities of human and social dynamics involved. This study illustrates the variability of within-country responses, highlighting the different levels of involvement from national and local governments, NGOs, and grassroots communities in disaster response efforts.

4.4. Mitigation and preventive measures for HILOs

The findings of this study indicate that the Indian Ocean tsunami in 2004, the Fukushima Nuclear Power Station accident, the COVID-19 pandemic in Indonesia, and the Rohingya refugee influx were characterized by a centralized governance approach. In contrast, the responses to the Glacial Lake Outburst Floods and the COVID-19 pandemic in Nepal were more decentralized. Notably, while the Nepalese government adopted a decentralized approach during the COVID-19 pandemic, the Indonesian government maintained a

centralized response. This centralised approach of relevant governments can be identified as a key factor affecting towards decisions related to mitigation and preventive measures. It can be argued that, with the exception of the nuclear power station accident, the other HILO disasters examined in this research encountered difficulties in securing adequate investments due to their HILO nature leading to lacuna of preventive measures. For instance, in the aftermath of the Indian Ocean tsunami in 2004, the nature and level of investment were indeed limited due to the High Impact Low Occurrence (HILO) nature of the disaster.

Further, due to the diversity of the HILOs the mitigation and preventive measure that should be taken following the HILOs was also different. For instance, in the context of Glacial Lake Outburst Floods, measures were frequently adopted, to maintain public awareness regarding the risks associated with such disasters and to promote long-term resilience strategies. During the COVID-19 pandemic in Nepal, earthquake preparedness was taught in schools but unfortunately had unintended negative consequences for children in one case. Students were instructed to hide under tables or beds during earthquakes; however, when a disaster occurred, children playing outside returned home to seek shelter as they had been taught, which tragically led to fatalities.

5. Discussion

As this study findings revealed, HILO disasters, by definition, occur infrequently but can have catastrophic consequences when they do where frequency versus severity becomes an important focus for the discussion. An analysis of six cases related data reveals that while events such as the Indian Ocean tsunami (2004) and the Great East Japan Earthquake (2011) are rare, their severity leads to significant loss of life and extensive economic damage. For instance, the tsunami resulted in approximately 230,000 fatalities across multiple countries, while the economic impact exceeded USD 2 billion in Sri Lanka alone. This disparity underscores the need for a nuanced understanding of risk that considers both the frequency and potential severity of HILO events.

Further, predicting HILO disasters remains a challenge due to their low-frequency nature and complex triggering mechanisms. While geological events like earthquakes can be somewhat anticipated, climatic events such as glacial lake outburst floods (GLOFs) are often unpredictable. The case of the Kedarnath GLOF in 2013 exemplifies this unpredictability, as rapid glacial melting led to catastrophic flooding with little warning. Enhanced monitoring technologies and predictive modelling are essential to improve forecasting capabilities for such unpredictable disasters.

In addition, preparedness levels for HILO disasters vary significantly across regions. Countries with established disaster management frameworks, such as Japan, exhibit higher preparedness levels through comprehensive training and resource allocation. Conversely, nations like Nepal, which experienced significant challenges during the COVID-19 pandemic, showed gaps in preparedness that exacerbated the crisis. Developing community-based preparedness programs and improving access to information can enhance readiness in vulnerable areas.

Effective resource allocation is crucial in mitigating the impacts of HILO disasters. Data indicates that countries that prioritize disaster risk reduction (DRR) in their national budgets tend to recover more efficiently. For example, Indonesia's early investment in healthcare infrastructure during the COVID-19 pandemic was instrumental in managing the crisis. However, disparities often exist, with marginalized communities receiving inadequate support. Ensuring equitable resource distribution is vital for effective response and recovery efforts.

Resilience is a critical factor in determining how communities withstand and recover from HILO disasters. Pre-existing social capital, adaptive capacities, and community cohesion significantly influence resilience levels. Research shows that communities with strong social networks are better equipped to respond to crises. For instance, local support systems in Sri Lanka post-tsunami facilitated recovery efforts, while the Rohingya refugee influx in Bangladesh revealed vulnerabilities in resource-limited areas. Hence, resilience varies significantly among the selected HILO events. In Sri Lanka, the Indian Ocean tsunami of 2004 prompted the development of community-based disaster management strategies,

enhancing local resilience. Conversely, Japan's experience with the 2011 Great East Japan Earthquake and subsequent Fukushima Nuclear Power Station accident showcased a well-established disaster preparedness framework, which included rigorous building codes and public education programs. In India, the Kedarnath GLOF of 2013 revealed the limitations of resilience in the face of rapid climate change and inadequate infrastructure, despite the region's historical experience with natural disasters. Both Indonesia and Nepal faced challenges in resilience during the COVID-19 pandemic, with pre-existing healthcare infrastructure deficiencies exacerbating vulnerabilities. Bangladesh's response to the Rohingya refugee influx highlighted the resilience of local communities, but also underscored their limited capacity to manage the sudden strain on resources.

HILO disasters encompass a diverse range of events, including hazard induced disasters (earthquakes, tsunamis, floods), biological disasters (pandemic) and sociological disaster (refugee influxes). Each type presents unique challenges and requires tailored response strategies. For example, the governance structures needed for managing a pandemic differ markedly from those required for natural disasters. This diversity necessitates a comprehensive risk assessment framework that considers the specific characteristics of each HILO type.

Governance plays a vital role in shaping the response and recovery efforts for HILO disasters. In Sri Lanka, the post-tsunami governance framework resulted in improved disaster management policies, although challenges in implementation remain. Japan's governmental response to the 2011 earthquake and Fukushima disaster was characterized by a high level of coordination and transparency, yet criticism arose regarding the nuclear regulatory framework. In contrast, India’s response to the Kedarnath GLOF was hampered by bureaucratic inefficiencies and inadequate disaster response protocols. The governance frameworks during the COVID-19 pandemic in both Indonesia and Nepal exhibited mixed effectiveness, with rapid policy adaptations in some areas but significant delays in others. In Bangladesh, the governance of the Rohingya crisis faced scrutiny due to inadequate resource allocation and the need for international cooperation. Effective governance mechanisms, characterized by transparency, accountability, and inclusive decision-

making, enhance the effectiveness of disaster management efforts. The Indonesian government's response to the COVID-19 crisis, including the establishment of referral hospitals, illustrates proactive governance. Conversely, inadequate governance can lead to mismanagement, as seen in the Rohingya crisis, where resource allocation and support systems were insufficient.

Equity is a crucial consideration in disaster management. Disparities in access to resources and support systems often exacerbate vulnerabilities among marginalized populations. Equity is a critical consideration in the context of HILO disasters. In Sri Lanka, the tsunami disproportionately affected marginalized communities, highlighting existing inequalities. Japan's robust disaster response mechanisms provided a more equitable recovery for affected populations, yet disparities persisted in the long-term impacts of the Fukushima disaster. The Kedarnath GLOF revealed significant inequities, as vulnerable populations lacked access to adequate resources and support. During the COVID-19 pandemic, both Indonesia and Nepal experienced significant inequalities in healthcare access, with lower-income groups disproportionately affected. During the COVID-19 pandemic, for example, vulnerable groups in Indonesia faced barriers to healthcare access, highlighting the need for equitable policies. The Rohingya refugee influx in Bangladesh exacerbated existing inequalities, as local communities faced increased competition for resources, leading to tensions and potential conflicts. Ensuring that all community members receive adequate support before, during, and after HILO events is essential for fostering resilience. It should be noted that although macroeconomic indicators such as GDP could return to trend just a few years after these HILO disasters, segments of the population that slide into poverty could take generations to recover; the recommended mitigation measures are cash handouts and livelihood generation (Deraniyagala, 2016).

Investment in disaster preparedness and response is crucial for mitigating the impacts of HILOs. In Sri Lanka, post-tsunami recovery efforts saw increased investment in infrastructure, although challenges in sustaining these improvements remain. Japan's substantial investment in disaster risk reduction measures following the 2011 earthquake has strengthened resilience, but questions about long-term sustainability remain. In India,

the lack of investment in infrastructure and preparedness contributed to the catastrophic impacts of the Kedarnath GLOF. The COVID-19 pandemic highlighted investment gaps in healthcare systems in both Indonesia and Nepal, emphasizing the need for ongoing commitment to public health infrastructure. In Bangladesh, insufficient investment in managing the Rohingya crisis has strained local resources, necessitating international aid and support.

Further, investment in disaster risk reduction and resilience-building initiatives is critical. Despite the clear economic benefits of investing in preparedness and mitigation measures, many countries still allocate insufficient resources to these efforts. For instance, the economic losses from the 2004 tsunami far exceeded the costs of implementing preventive measures. Encouraging public-private partnerships and international collaboration can enhance funding for resilience-building activities.

Maintaining awareness of HILO risks is essential for effective disaster management. In Sri Lanka, the tsunami increased public consciousness about disaster preparedness, leading to community engagement initiatives. Japan's experience with the 2011 disasters has fostered a culture of preparedness, although complacency remains a concern. The Kedarnath GLOF underscored the need for greater public awareness of climate change impacts. During the COVID-19 pandemic, both Indonesia and Nepal faced challenges in maintaining public consciousness about health risks, impacting response efforts. In Bangladesh, the ongoing Rohingya crisis has raised awareness among officials and the public about the complexities of humanitarian responses, although local communities still require more support and education on the issue. Hence, raising awareness about HILO disasters among officials and the public is important for improving preparedness and response strategies. Continuous education and training programs can foster a culture of resilience and vigilance. For instance, community workshops and simulation exercises can enhance public understanding of risks and appropriate responses, thereby improving overall resilience. In addition, participation in drills would significantly increase awareness. The Indian Ocean Wave (IOWave) exercise, conducted every few years are a good example of

region wide preparedness, with elements of the exercise reaching down to the 'last mile' category as well (Sakalasuriya et al. 2021).

The study findings indicate the need for identifying strategies to improve resilience against HILOs. Strengthening community-based preparedness, implementing local training programs and establishing emergency response teams can enhance community readiness for HILO disasters is a crucial step. Further, enhancing early warning systems, investing in advanced monitoring technologies and communication networks can improve disaster prediction and response times. Promoting inclusive governance while engaging diverse community stakeholders in disaster-related planning and response ensures that all voices are heard and needs are met. Equitable resource distribution and developing policies that prioritize support for marginalized communities can enhance overall resilience and mitigate disparities is also another step. In addition, investing in infrastructure, allocating resources for resilient infrastructure, such as flood defences and healthcare facilities, can significantly reduce the impact of HILO disasters.

Fostering public awareness and education about HILO risks and preparedness measures through community engagement initiatives can cultivate a proactive culture of resilience. By addressing these strategies, communities can build resilience against HILO disasters, ensuring better preparedness, response, and recovery in the face of future challenges. The comparative analysis of these HILO disasters highlights the complexities and interconnections between resilience, governance, equity, investment, and public consciousness. Each HILO event presents unique challenges and lessons that can inform future disaster management strategies. By addressing these themes, stakeholders can enhance preparedness, response, and recovery efforts in the face of high-impact, low-probability disasters.

5. Conclusions: Lessons and Strategies

The following lessons and strategies can be identified through the analysis of six major HILO disasters in six different contexts (see Table 1), supplemented by insights from the HILO workshop held in Colombo Sri Lanka in September 2024.

1. One of the greatest assets to face HILO disasters is the social capital built up in countries (e.g. through education) that produces resilience, especially in the response phase. As such the strengthening of local communities appears to be a priority for preparedness, especially given that such community responses played a significant role in many of the HILO disasters studied.
2. Where recovery is concerned however, existing social disparities may be exacerbated, especially if vulnerable communities slide into poverty.
3. One key difference between the biological (i.e. Covid) disasters and the others was that the civil society and general public response was both constrained and restrained by the contagious nature of the pandemic that afflicted those affected.
4. The role of governments is very important, in all phases, especially in the response phase, but also in the preparedness and recovery phases. Depending on the context and type of disaster, a mix of centralized and decentralized approaches were used, with advantages and disadvantages in both. In addition, with the exception of the refugee crisis in Bangladesh, international assistance played a role, here too with both benefits and detriments.
5. Out of the six countries considered, Japan stood out as an exception that fared well, with respect to preparedness, plans for disaster management, equity, and ability to make investments against HILOs. Japan had by far the highest GDP per capita (see Table 1).
6. The reluctance to make investments to prepare for HILO disasters was evident, perhaps apart from the case of Japan. One alternative to structural investments could be to increase awareness through education and drills, one example of which is the IOWave exercise for the relatively rare tsunamis in the Indian Ocean.

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5. Lessons Learnt, Best Practices and Strategies for Resilience

The following lessons and strategies can be identified through the analysis of six major High Impact Low Occurrence (HILO) disasters in six different contexts, supplemented by insights from the HILO workshop held in Colombo Sri Lanka in September 2024, including the participant feedback itemized in Annex 5.

1. One of the greatest assets to face HILO disasters is the social capital built up in countries (e.g. through education) that produces resilience, especially in the response phase. As such the strengthening of local communities appears to be a priority for preparedness, especially given that such community responses played a significant role in many of the HILO disasters studied.

2. Where recovery is concerned however, existing social disparities may be exacerbated, especially if vulnerable communities slide into poverty. A focus on cash transfers and restoring livelihoods during the recovery stage could help to combat this.

3. One key difference between the biological (i.e. Covid) disasters and the others was that the civil society and general public response was both constrained and restrained by the contagious nature of the pandemic that afflicted those affected.

4. The role of governments is very important, in all phases, especially in the response phase, but also in the preparedness and recovery phases. Depending on the context and type of disaster, a mix of centralized and decentralized approaches were used, with advantages and disadvantages in both. In addition, with the exception of the refugee crisis in Bangladesh, international assistance played a role, here too with both benefits and detriments.

5. Out of the six countries considered, Japan stood out as an exception that fared well, with respect to preparedness, plans for disaster management, equity, and ability to make investments against HILOs. Japan had by far the highest GDP per capita (see Table 1in Sections 2 and 4). This would suggest that getting out of poverty would be the most effective measure for resilience against disasters.

In a sense the above would relate to all disasters, whether HILO or not. The following would be specifically relevant to HILO disasters.

6. The reluctance to make investments to prepare for HILO disasters was evident, perhaps apart from the case of Japan. This is because they occur infrequently, and there are demands to cater for disasters that occur more frequently albeit with less impact (e.g. floods, drought, high winds compared to tsunamis).

7. In this context, any structural investments would need to be cost-effective (e.g. small increases in column sizes for post-disaster buildings) and also synergistic (e.g. such size increases would improve resilience against multiple disasters and also enhance durability as well).

8. Greater focus should be placed on non-structural investments, for example on evacuation drills. One example of this is the IOWave exercise (once every 2-3 years) for the relatively rare tsunamis in the Indian Ocean. Consideration could be given to such exercises for biological disasters too, especially since they tend to have cross-border impacts as well, even for example to implement a global lockdown for a very limited duration – e.g. once in five years.

9. Another non-structural measure would be to preserve awareness of HILO disasters across generations, since they occur so infrequently. Memorialization is one way to do this, but perhaps more effective would be to create awareness through school curricula. This could be both through the inclusion of content in science, environment or civics curricula, and the introduction of stories in primary and secondary school readers that capture relevant HILO disasters vividly – e.g. the story of Hamaguchi Gohei included in Japanese school books.

6. Outcomes and Impacts (including Dissemination)

6.1. Outcomes

The following can be seen as the outcomes of the entire process of studying of HILO disasters by the NASSL with IAP/AASSA support.

1. The study built on the IAP experience of studying disasters, but extended it by focusing on HILO disasters.

2. It resulted in a set of lessons learnt, best practices and strategies for resilience, listed in Section 5 of this report. In addition, a potential journal paper (in draft form) and a short video on the workshop have been prepared.

3. The study process built on NASSL's partnerships with regional academies in India, Bangladesh and Nepal; and generated new partnerships with Japan and Indonesia. Although the Ajerbaijan academy (new to IAP) indicated initial willingness to participate and joined some initial online discussions, it was not able to continue. In addition, although contact was made with a Fellow of the (non-IAP) Australian Academy of Engineering and Technology (AAET) to serve as an expert, this too did not materialize. Nevertheless such relationships can be pursued further.

4. NASSL also demonstrated its capability for successfully leading studies of this nature, having won four IAP/AASSA grants based on submitted proposals over the past five years.

5. NASSL also continued its engagements with Sri Lanka's young academy (Sri Lanka Association of Young Scientists – SLAYS) and the IAP Young Physician Leader (YPL) community in Sri Lanka. It is anticipated that Sri Lanka's YPL community would appoint a coordinator towards the end of knowledge exchange, as a result of discussions that took place at the workshop. Furthermore, the NASSL recruited two subject matter experts (a sociologist and disaster management specialist), in spite of their not being Fellows, in order to spearhead and enhance the analysis.

6. Another new departure was the presence of H.E. Semih Turgut, the Turkish Ambassador to Sri Lanka, at the opening ceremony. This has the potential of engaging the diplomatic community as a whole in NASSL activities and disseminations.

6.2. Impacts (including Dissemination)

The following can be seen as the impacts (both realized and potential) of the study on HILO disasters.

1. The timing of the event coincided with national and global events surrounding the 2004 Indian Ocean Tsunami in particular. For example, the Disaster Management Centre (DMC)

of Sri Lanka had an international technical symposium on 4 November 2024 (the day before World Tsunami Awareness Day) on the topic "Reflections on two decades from tragedy to resilience: Retrospect of the 2004 Indian Ocean Tsunami". This was supported by the UN agencies United Nations Development Program (UNDP), United Nations Children's Fund (UNICEF) and International Organization for Migration (IOM). Professor Priyan Dias (Fellow NASSL and main organizer for the HILO workshop) was invited as the keynote speaker, and was able to share some insights gained from the NASSL workshop regarding best practices for increasing resilience against HILO disasters such as tsunamis. Furthermore, he was interviewed for a video documentary (to be released in December 2024) with UNDP and DMC collaboration on the topic of the DMC technical symposium.

2. A write-up of the study, that included some of the Lessons Learnt, Best Practices and Strategies for Resilience (Section 5 of this report) was submitted to the IAP E-bulletin.

3. It is intended that the key conference outputs – i.e. (i) Lessons Learnt, Best Practices and Strategies for Resilience (Section 5); (ii) Short Video (see link below; also Annex 6); (iii) Journal paper when published (Section 4) – will be circulated to both actual and potential participants (who were contacted prior to the workshop) – see Annex 4. The use of UN agencies and the diplomatic community will also be explored.

https://nassl.org/resilience-to-high-impact-low-occurrence-hilo-disasters-a-cross-sector-comparison/

Annex 1 – Template for Case Studies

Preamble - Please provide a brief description of the High Impact Low Occurrence event you are focusing on, with dates, impacts (economic, human), timescale (of event, recovery); and any other relevant details (max 500 words).

1. What was the understanding of the risk concerned prior to the disaster?
   - among specialists
   - among government
   - among people

2. Was there any underplaying of the risk and why?
   - economic constraints
   - governance decisions

3. What was the initial response and when and from where?
   - Organized by government
   - Organized by civil society
   - Spontaneously by public

4. Was there any risk for first responders?
   - natural, technological, epidemiological

5. What was the effect of such perceived risk on the first response?
   - constraint/delay on response?
   - response confined to official means?

6. What was the main focus of those not affected?
   - flight/"fight"

7. How effective was the (a) preparedness, (b) resilience and (c) response? With respect to
   - Immediate succour
   - Return to normalcy

8. Was there anything that increased preparedness before the disaster, in spite of being a HILO one?

9. What dimensions of resilience helped to face the disaster?
   - Economic standing
   - Social capital
   - Religious/cultural dimensions

10. Was there inequity in the effects of the disaster, response and recovery among different categories: e.g. rich/poor; male/female; urban/rural; educated/uneducated; majority/minority; young/old etc.

11. What was the timescale of (i) the event; (ii) the recovery

12. Did the post-recovery measures reduce the above inequities or increase them or maintain them?

13. What was the effect of the disaster on subsequent governance?
- more centralized or decentralized?
- more securitized or community based?

14. What was the level of investment made for future resilience?
- By government?
- By communities?
- By business?
- By individuals?

15. Was the nature and level of investment limited because of the HILO nature of the disaster?

16. Did the investment for a future HILO disaster also have any benefits (or detriments) for everyday life?

17. Did the investment constitute a "build back better" scenario?
- For the majority?
- For the most vulnerable in society?

18. What measures if any were adopted to keep the HILO disaster in public consciousness?

19. What were (i) the international community's responses to the event; and (ii) the within-country responses to such international responses: (a) at the national level; (b) at the local community level?

20. How good was science communication (a) during the event; and (b) after the event. Were there any deficiencies?

21. How was technology deployed during and after the event? (e.g. communications, mobile phones, mobile phone Apps, databases etc). Were there any deficiencies?

Annex 2 - Analysis of Case Studies

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Methodology

Following the qualitative approach, the study employs summative content analysis method in order to analyze data gathered from six countries. Qualitative analysis involves a process of reduction, while summative analysis seeks to identify the fundamental components of a text and assess its overall significance. The term "essential text" in the context of summative analysis pertains to those aspects of the text that provide insights into the overall meaning of the text and contribute to its significance. These essential text elements may include contextual information, personal experiences and emotional content (Rapport, 2010). In the examination of HILO disasters data and information sheet, the study scrutinized similarities, differences, and lessons learned from each disaster in a comparative manner, following the framework of 21 key questions established at the outset of the research. First the study looked into comparison in term of the disaster and at the second stage the study examined context specific content appropriately.

Table 1 : Snapshot of the country specific HILO disaster

Country	Disaster	Date/s of the event
Sri Lanka	Indian Ocean tsunami 2004	26th December 2004
Japan	The 2011 Geart East Japan Earthquake Disaster and the Fukushima Nuclear Power Station Accident	11 March 2011, a giant earthquake (Magnitude 9.0) occurred off Tohoku, Japan, generating a devastating tsunami.

India	Glacial Lake Outburst Floods (GLOF) at Kedarnath temple town in 2013 (Kedarnath GLOF in 2013) in the Uttarakhand Himalaya, India	Flash floods over a few days during 14th to 17th June 2013
Nepal	Covid 19 pandemic	January 2020 to October 2022
Indonesia	Covid 19 pandemic	January 2020 to December 2022
Bangladesh	Impacts of Rohingya Refugee Influx on Groundwater System of Cox's Bazar Region in Bangladesh and Potentials for Conflicts.	The main event of influx lasted for about three months. The influx began on 25 August 2017, after the Myanmar Army launched security operations in northern Rakhine state

For the purpose of facilitating comparison, disaster events were predominantly classified into four primary categories: (1) Pre-disaster phase encompassing awareness, early warning systems, and preparedness measures; (2) During disaster phase involving response strategies; and (3) Post-disaster phase focusing on recovery efforts and (4) Mitigation, resilience and assimilation of lessons learned.

Analysis

1. Pre-disaster phase: awareness, early warning systems, and preparedness measures

1.1 Understanding of the risk prior to the disaster among the government, specialists, and people

Cross all countries, whether facing disasters such as tsunamis, nuclear power plant accidents, floods, the Covid-19 pandemic, or Rohingya refugee influxes, a common theme emerges: a lack of awareness and preparedness among all governmental authorities, experts and people. In Sri Lanka, for instance, there was a complete lack of awareness regarding the tsunami risk among all parties, while in Japan, awareness of the tsunami and earthquake risks existed among all parties but not of the hazards associated with nuclear power stations. However, in the disasters such as flooding, environmental and water resource management authorities in India demonstrate awareness of the potential risks stemming from climate change effects on glaciers and water bodies within the challenging terrains of the Himalayas. Despite this awareness, the implementation of effective policies and investments in infrastructure for disaster risk reduction remains inadequate. Indian local administrative bodies exhibit varying levels of comprehension regarding specific risks associated with flash floods or landslides triggered by intense rainfall. While general disaster management plans are in existence, the unprecedented scale and suddenness of the 2013 Kedarnath GLOF event surpassed anticipated scenarios, revealing deficiencies in emergency preparedness and infrastructure resilience, particularly in the face of flash floods. The capacity for proactive measures such as land-use planning and evacuation strategies is also constrained. Both the Nepali and Indonesian governments were ill-prepared for the Covid-19 pandemic. Nepal enforced a nationwide lockdown from March 24 to July 21, 2020, primarily relying on lockdown measures for control. Indonesia implemented a range of policies, including designating 100 domestic general hospitals as Referral Hospitals and launching a website to provide real-time data on the impact of Covid-19 in the country. Notably, among the disasters scrutinized in this study, it is reported that only the Bangladeshi government exhibited some level of awareness regarding the potential occurrence of such incidents since the onset of insurgent activities in Rohingya Refugees in 2017.

In Japan, a prevalent belief in the "safety myth" regarding nuclear power stations was commonly held among the population. Similarly, during the Kedarnath flood disaster in India, local residents and pilgrims displayed a lack of awareness regarding the potential risks. While some locals may have possessed traditional knowledge about the hazards of residing in flood-prone river valleys and steep slopes, the availability of timely and accurate information or resources for disaster preparedness was insufficient. Both Nepal and Indonesia found themselves unprepared and uninformed about the Covid-19 pandemic, with initial misconceptions among Nepalese individuals that they were immune to the virus. However, in Indonesia, community perceptions of the early stages of the COVID-19 pandemic significantly influenced citizens where they conducted a study two months after the country's first reported case. A study involved 1,043 online respondents revealed that the respondents demonstrated awareness of COVID-19 as a viral disease transmitted through saliva droplets (97.1%) and contaminated surfaces (86.5%). In Bangladesh, individuals were unaware of the magnitude of risks associated with the events that transpired.

The study findings suggest lack of awareness among the government, experts and people coupled with scale and suddenness of the disaster event leading towards high impact of such low occurrence disasters in the Asian region.

1.2 Underplaying of the risk due to government decisions coupled with economic constraints

According to the study findings, disasters such as tsunamis, nuclear power station accidents, and the influx of Rohingya refugees were not adequately recognized as risks, primarily due to their infrequent occurrence. However, certain policy measures were not effectively implemented at the grassroots level, revealing gaps in implementation, particularly in the case of Japan. In Sri Lanka, the risk was not downplayed due to a lack of awareness across all sectors regarding the Indian Ocean tsunami disaster. In Japan, regarding earthquake risks, the government updated the long-term earthquake forecast in the early 2000s, requiring both companies and regulators to take them into account. Nevertheless, there was a lack of proper implementation. For instance, one recommendation was to increase the design tsunami height, but this was seldom put into practice. This was partly due to economic considerations but primarily because of uncertainties in assessments. Similarly, the underestimation of disaster risks in the Himalayas often results from a combination of economic limitations, governance decisions prioritizing short-term gains, and cultural factors. Additionally, the risk of the Rohingya refugee influx was underestimated as the scale of the influx was not perceived. Although successful repatriation occurred in previous instances, this did not happen after 2017. The government attempted to raise awareness of the issue to the international community due to resource constraints faced by the Bangladeshi government in addressing the matter.

The underestimation of risk, combined with economic factors, was observed in both Nepalese and Indonesian contexts, highlighting the unique nature of the Covid-19 pandemic. During the pandemic, lockdown measures led to economic challenges for individuals in both countries. Medical professionals, including doctors, nurses, and hospital staff, faced risks as they were unable to reside in their usual accommodations for fear of spreading the disease. The closure of businesses resulted in job losses for many daily wage workers, significantly impacting the livelihoods of the Nepalese population. In Indonesia, the pandemic severely affected the economy, leading to increased unemployment, rising poverty levels, a widening wealth gap, decreased GDP, and reduced domestic and international trade. These consequences were driven by restrictions on community activities, reduced physical interactions, and business terminations due to declining

sales. The economic repercussions persisted, with Indonesia experiencing a sharp decline in growth to -5.32% in the second quarter of 2020 compared to 5.05% growth in the same period in 2019 (Badan Pusat Statistik, 2020).

Given that the Covid-19 pandemic, despite its low frequency nature, can be considered an underestimated disaster. Due to governmental decisions and economic limitations, it is crucial to recognize that existing governance frameworks are insufficient to effectively address the pandemic in Nepal and Indonesia. Therefore, urgent reforms in health governance are imperative, necessitating a shift towards universal health coverage and health security for all populations across all nations. This transformation demands robust global health diplomacy rooted in knowledge-sharing, solidarity, and collaborative negotiations to effectively combat the ongoing challenges posed by the Covid19 pandemic.

1.3 Effectiveness of preparedness during immediate succour

While Sri Lanka lacked effective preparedness for tsunami disasters, previous experiences with flooding may have facilitated immediate relief efforts. In contrast, Japan demonstrated strong preparedness measures, swift initial responses, including efficient evacuation and rescue operations. The study findings underscore the stark differences in preparedness and emergency responses between the two countries facing similar disaster contexts. Sri Lanka's lack of readiness for tsunamis contrasts with Japan's proactive approach, stemming from prior tsunami experiences that enabled smooth evacuations during the Fukushima Nuclear Power Station Accident. Similar to Sri Lanka, India encountered challenges related to preparedness and rapid emergency responses during Glacial Lake Outburst Floods. During the Covid-19 pandemic in Nepal and Indonesia, initial preparedness was deficient, with lockdown strategies proving beneficial in later stages. Likewise, in Bangladesh, although the Government of Bangladesh established the Office of the Refugee, Relief and Repatriation Commissioner in Cox's Bazar to address previous influxes, there was inadequate readiness to accommodate a large number of refugees.

Overall, a lack of effective preparedness was evident across all contexts for tsunamis, flooding, Covid-19, and Rohingya refugee influxes, with Japan standing out as an exception for its successful handling of tsunamis and nuclear power plant accidents in terms of preparedness. Moreover, with the exception of Japan, all other countries acknowledged the need to enhance preparedness, particularly given the high-impact, low-occurrence (HILO) nature of these particular disasters. The study findings emphasized the critical significance of implementing a reliable early warning system for such HILO events. This system should cater to not only the disaster-specific needs but also address the socio-economic and cultural considerations unique to each context.

1.4 Science communication during and after HILO disaster events

In the aftermath of the Indian Ocean tsunami in 2004, science communication was largely absent. During the Fukushima Nuclear Power Station accident, however, the period of radioactive contamination was marked by confusion in science communication, stemming from the presence of multiple voices rather than a unified message. In the context of Glacial Lake Outburst Floods, science communication faced substantial obstacles amid the ongoing disaster. Initially, shortcomings in early warning systems for flash floods and landslides intensified the difficulties associated with providing timely alerts to both residents and tourists in the affected region.

During the COVID-19 pandemic in Nepal, effective science communication became crucial for accurate data collection. Understanding the demographic composition of society—

including language, education levels, and age groups—was essential for preparing informational materials, designing programs, training communicators, and implementing communication processes in response to the pandemic. However, obtaining reliable data during the nationwide lockdown posed significant challenges. In Indonesia, science communication evolved rapidly during the COVID-19 pandemic to address the urgent need for information regarding the virus. However, the dissemination of inaccurate, misleading, and misinterpreted scientific information posed risks to both social cohesion and individual well-being. Effective strategies to mitigate the spread of misinformation included utilizing celebrities, religious leaders, esteemed scientists, and relevant officials as science communicators or influencers to convey trustworthy information to the public through various media platforms. Additionally, training these influencers and science communicators to convey information in simple and appropriate language tailored to specific target audiences (e.g., grassroots communities, children, educators, and trainers) was essential. Where necessary, the use of local languages facilitated better understanding among local populations.

In the case of the Rohingya refugee influx, opportunities for scientific communication were largely non-existent at the onset of the crisis. Responses were focused on urgent humanitarian needs, such as the drilling of thousands of shallow wells to provide water supplies. Unfortunately, the microbiological contamination of these shallow wells led to frequent outbreaks of diarrheal disease among the population.

The findings of this study underscore the necessity for well-developed early warning systems in which science communication is integral both during and after High Impact Low Occurrence (HILO) disaster events. The existed science communication also indicated shortcomings emphasizing the need of rapid evolvement.

2. During disaster phase involving response strategies

2.1 Initial responses by government

The research findings suggest how diverse actions undertaken by governments during the disaster phase. In response to the Indian Ocean tsunami, the Sri Lankan government repurposed schools as refugee shelters. Highlighting the Japanese government's readiness, a tsunami warning was swiftly issued three minutes after feeling the seismic tremors from a widespread earthquake. The Fukushima Dai-ichi accident, specifically the station blackout, was promptly reported to the government by TEPCO (Tokyo Electric Power Company) at 15:42, leading to the declaration of a state of emergency at 19:03. The Fukushima prefecture promptly issued evacuation orders for residents within a 2 km radius of the Fukushima Dai-ichi Nuclear Power Station. In the event of Glacial Lake Outburst Floods in India, the Indian Army and Air Force promptly mobilized military and paramilitary units for immediate search and rescue efforts. Helicopters played a pivotal role in evacuating stranded pilgrims and locals from the affected regions. Coordination among government agencies like the National Disaster Response Force (NDRF) and State Disaster Management Authority (SDMA) facilitated emergency relief operations effectively. During the Rohingya refugee influx, the Bangladesh government permitted Rohingyas to seek refuge across the border, providing essential security, food, and emergency medical services. Efforts were made to alert the international community for urgent assistance.

The study findings show across all disasters, governments established relief camps to offer shelter, sustenance, and medical aid to affected individuals as an initial emergency response to

tsunamis, nuclear accidents, floods, and refugee influxes. Conversely, in response to the Covid-19 pandemic, both the Nepalese and Indonesian governments implemented various measures such as endorsing universal personal protection, enforcing physical distancing, imposing localized lockdowns, travel restrictions, isolation protocols, and selective quarantines. In Indonesia, the government regulated the Large-Scale Social Restrictions (PSBB) to control large-scale social interactions and provided social aid to citizens to sustain economic activities within the community. It can be argued that unlike localized disasters such as tsunamis, nuclear power plant accident, flooding and refugee influx, the Covid-19 pandemic was a global health crisis that governments had to navigate complex international dynamics, including travel restrictions, trade disruptions, and varying levels of global cooperation in response to the pandemic where governments had to take specific actions compared to other HILO disasters in the region.

2.2 Initial responses by civil society

A consistent feature observed across all high impact, low occurrence (HILO) disasters examined in this study was the active involvement of civil society in response efforts. In Sri Lanka, religious sites were repurposed as refugee shelters. In Japan, local government authorities at the prefecture, city, and village levels issued evacuation orders and provided assistance to residents. In India, numerous civil society members played a pivotal role in delivering humanitarian aid and relief services to affected communities. Volunteers participated in rescue operations, distributed essential supplies such as food and medical assistance, and organized temporary shelters. Community groups and religious organizations effectively managed resources and extended support to impacted families, coordinating relief initiatives and addressing the immediate needs of vulnerable populations. In Nepal, amidst the Covid-19 pandemic, the public assisted one another. For instance, individuals in need, including those who were ill or in isolation, received food aid. Indonesia implemented six social safety net programs (JPS) to alleviate the impact of COVID-19 on marginalized groups. These initiatives encompassed expanding the Family Hope Program (PKH), issuing Staple Food Cards, offering Pre-Employment Cards, providing electricity subsidies, enhancing market and logistical operations, and granting credit payment relief for informal workers. Additionally, voluntary workers from non-governmental organizations (NGOs) and individuals received training from healthcare professionals to aid victims in care facilities and hospitals. In Bangladesh, NGOs and religious groups were among the first responders, followed by a diverse range of civil society organizations, in addressing urgent needs. Efforts involved establishing temporary shelters and water wells, among other essential interventions to support affected communities. The active engagement of civil society entities across these HILO disasters underscored their crucial role in facilitating response and recovery processes, showcasing resilience and solidarity in times of crisis.

2.3 Initial responses by general public

Parallel to the responses from civil society, the general public also played a significant role across various HILO disasters. In Sri Lanka, individuals offered emergency shelter, transportation, food, and clothing to those affected by the disaster. Remarkable frontline work was carried out, with the Ministry of Health establishing a network of safe houses through local initiatives to provide affected individuals with shelter, sustenance, and accommodation. Basic educational facilities were also established in the absence of immediate funds or resources due to stretched emergency services. Coastal residents took proactive measures by evacuating to higher ground to ensure their

safety. In India, local residents and unaffected visitors united to engage in rescue operations, deliver immediate assistance, and support evacuation processes. Community members and locals demonstrated spontaneous solidarity by providing essential aid, such as food and shelter for those stranded, assisting in the evacuation of the injured, and participating in clean-up and recovery endeavours. Similarly, in Bangladesh, the general public opened their homes and properties to offer shelter, food, and water to refugees. However, with the highly contagious nature of Covid-19, individuals in Nepal and Indonesia began practicing social distancing as a preventive measure. During this period, people joined forces to combat the pandemic, offering various forms of support within their means. Notably, in Japan during the nuclear power plant accident, affected individuals were compelled to comply with directives from local authorities rather than the general public responding independently. This unique response dynamic underscores the diverse approaches taken by communities in different disaster scenarios, highlighting the importance of coordinated efforts and adaptive strategies to effectively address the challenges posed by HILO disasters.

2.4 Natural, Technological, and Epidemiological Risks Associated with First Responders

This study categorizes various disasters based on existing literature, identifying the 2004 Indian Ocean tsunami and Glacial Lake Outburst Floods as "natural" disasters, while the Fukushima Nuclear Power Station accident is classified as a technological disaster. The COVID-19 pandemic in Nepal and Indonesia is recognized as an epidemiological disaster, and the Rohingya Refugee Influx is characterized as a human and social disaster. Moving beyond these classifications, this section aims to examine the natural, technological, and epidemiological risks faced by first responders in each of the disasters analyzed in this research.

In the immediate aftermath of the 2004 Indian Ocean tsunami in Sri Lanka, first responders were confronted with the risk of subsequent waves. The disaster elicited a remarkable social response, characterized by widespread volunteerism. Additionally, there existed a potential risk of structural collapse from damaged buildings during initial response efforts, which can be categorized as risks related to the built environment. However, no significant technological or epidemiological risks were reported in this context. Regarding the Fukushima Nuclear Power Station Accident, local government officials and volunteer firefighters took it upon themselves to encourage and guide residents to evacuate following the tsunami warning. The Fukushima Dai-ichi Nuclear Power Station experienced a blackout, exposing workers to risks of explosion and radiation. Therefore, both the workers at the facility and residents of surrounding areas faced heightened risks of radiation exposure. Further, first responders were at substantial risk of injury or loss of life due to unstable slopes, debris flows, mass movements, and rapidly rising water levels caused by Glacial Lake Outburst Floods.

In the context of the COVID-19 pandemic, first responders faced significant risks, as the situation proved life-threatening in both Nepal and Indonesia. Primarily, the lack of public knowledge regarding the virus and health protection measures posed direct threats to individual safety. Initially, experts provided critical explanations regarding the virus’s behavior, community protection strategies, and necessary actions upon exposure. These experts became prominent figures in traditional and social media, serving as key influencers during a period marked by a dearth of reliable information. Subsequently, technological communication platforms emerged to facilitate exchanges among various groups and communities. Nonetheless, the proliferation of excessive information, ranging from accurate to misleading or false, created confusion among the public.

The Rohingya Refugee Influx presented significant challenges, with a staggering number of refugees sometimes surpassing the local population. This influx resulted in a critical shortage of resources, including space, shelter, and sanitation facilities. The challenging terrain compounded the risks, including an increased likelihood of landslides. Furthermore, severe shortages of water and medical care heightened the risk of diarrheal diseases, which adversely affected the first responding local communities.

Hence, all high-impact, low-occurrence (HILO) disasters examined in this research indicated life-threatening risks for first responders, with the exception of the Rohingya Refugee Influx, where both refugees and host communities faced a multitude of risks linked to water scarcity and various socio-cultural factors.

2.5 Effect of Perceived Risk on First Response: Constraints or Delays in Action, or Response Limited to Official Means?

In the context of the 2004 Indian Ocean tsunami, there was no significant perception of risk among first responders. Conversely, during the Fukushima Nuclear Power Station accident, many workers chose to remain at the facility, despite the occurrence of hydrogen explosions. Their decision was motivated by the imperative to prevent a reactor explosion and ensure the safe cooling of the system. In the case of the Glacial Lake Outburst Floods, hazards such as landslides, avalanches, and flooding can impede the timely initiation of rescue operations. Damage to critical infrastructure, including roads, bridges, and communication networks, can obstruct the movement of response teams and the mobilization of necessary equipment. As a result, first responders may encounter obstacles in reaching remote or isolated communities that urgently require assistance. During the initial outbreak of the COVID-19 pandemic, the constraints on response were particularly acute, as the situation posed life-threatening risks to those infected. First responders faced a high probability of contracting the virus, further complicating response efforts. In contrast, the Rohingya Refugee Influx exhibited no delays in spontaneous responses, as there was a lack of perceived risk associated with entering the affected areas. Additionally, some responders drew upon their experiences from previous incidents in the 1990s, which informed their approach to managing the influx. Although there was no perceived risk during the Indian Ocean tsunami, various perceived risks were observed in other disasters, primarily those that threatened lives. Notably, during the Fukushima Nuclear Power Station accident, it was reported that many officials and volunteers—numbering in the hundreds—lost their lives because the tsunami struck prior to their evacuation.

2.6 The Main Focus of Those Not Affected: “Flight” or “Fight”

In the aftermath of the 2004 Indian Ocean tsunami, the predominant response among those unaffected was one of "fight." Individuals mobilized to assist in any way possible, demonstrating a strong commitment to aid those in need. Similarly, during the Fukushima Nuclear Power Station accident, many Japanese nationals were indirectly affected by power failures, ongoing rescue operations, and the potential risks associated with severe explosions at the nuclear facility. Even those who were not directly impacted displayed considerable sympathy and concern for affected individuals. In the case of Glacial Lake Outburst Floods, individual responses varied; some individuals prioritized personal safety and risk mitigation, while others expressed solidarity and took proactive measures to support recovery and resilience-building initiatives within disaster-prone areas. This variability was largely influenced by contextual factors, available resources, and

individual priorities. During the COVID-19 pandemic, individuals who were not directly affected were compelled to maintain physical distance from others as a precautionary measure. In this context, they actively sought to contribute to the response, even in the absence of complete clarity regarding the credibility of their actions. In the case of the Rohingya Refugee Influx, those not directly affected also exhibited a strong "fight" mentality, engaging in various forms of assistance as circumstances allowed. Consequently, with the exception of the nuclear power station incident, individuals in all other scenarios demonstrated a willingness to "fight" by doing whatever was feasible to support those impacted by the crises.

2.7 Inequity in the Effects of Disaster: Responses Among Different Social Groups

The Indian Ocean tsunami of 2004 had widespread effects across all sectors of society; however, certain groups experienced disproportionately greater impacts. Notably, impoverished individuals residing in precarious housing along the coast were among the most severely affected, alongside women, children, and the elderly. The responses to the disaster varied significantly among these social groups. For instance, those living in poverty relied heavily on governmental, civil society, and community support for assistance. Furthermore, areas situated farther from the capital city of Colombo received fewer services compared to those located in closer proximity. In the case of the Fukushima Nuclear Power Station accident, the tsunami damage and radiation exposure affected individuals equally; however, there were discernible inequities in the subsequent response and recovery processes. Approximately two-thirds of the victims were elderly individuals (aged 60 years and older), largely due to challenges associated with rapid evacuation. Similar patterns of inequity were observed during glacial lake outburst floods, where marginalized communities and informal workers, predominantly from lower-income backgrounds, faced disproportionate consequences. This was largely attributable to their limited access to resources, inadequate housing, and reliance on precarious livelihoods. The COVID-19 pandemic further illustrated the pervasive nature of such inequities, affecting individuals irrespective of socioeconomic status, gender, urban or rural residence, educational background, majority or minority status, and age. During the Rohingya refugee influx, the disaster impacted all sectors of society; nevertheless, vulnerable populations such as the elderly, women, and children were particularly at risk. Regardless of the specific type of disaster, it has been observed that the responses of different social groups are largely influenced by their socio-economic identities.

3. Post-disaster phase focusing on recovery efforts

3.1 Timescale of the event and recovery

Table 2: Timescale of the event and recovery

Country	Disaster	Date/s of the event	Time scale of the event	Time scale of the recovery
Sri Lanka	Indian Ocean tsunami 2004	26th December 2004	A matter of hours. Two waves. The time for the waves to arrive on the West coast was around an hour later than on the East coast. There was also a second	**6 months** : resumption of education activities and restoration of rail and road networks,

			wave that was greater in intensity than the first one, with a delay of around half an hour in between.	telecommunication networks. **5 years:** e.g. housing and school reconstruction. **More than 10 years**: Businesses.
Japan	The 2011 Geart East Japan Earthquake Disaster and the Fukushima Nuclear Power Station Accident	11 March 2011, a giant earthquake (Magnitude 9.0) occurred off Tohoku, Japan, generating a devastating tsunami.	The tsunami damage occurred within hours of the earthquake. The radioactive release was mostly within a month of the earthquake.	The contamination continued for years. The recovery from the tsunami damage took years, and now it is almost completed. However, the recovery from radioactive pollution still continues after more than a decade.
India	Glacial Lake Outburst Floods (GLOF) at Kedarnath temple town in 2013 (Kedarnath GLOF in 2013) in the Uttarakhand Himalaya, India	Flash floods over a few days during 14th to 17th June 2013	Immediate Event **2 days (June 16-17, 2013)**: June 16, 2013: Incessant rainfall and fast melting of Chorabari Glacier led to swelling of the Mandakini River. June 17, 2013: Rainfall, landslides and breaching of Chorabari Lake caused massive destruction in the Kedarnath town and surrounding areas.	Short-Term Response (2013-2014): Short-Term Response (2013-2014): Long-Term Rehabilitation (2017-Present):
Nepal	Covid 19 pandemic	January 2020 to October 2022	December 2019 till 2022	Although covid pandemic has determined ended, but the recovery is still being continued, mainly to promote economic development.
Indonesia	Covid 19 pandemic	January 2020 to …….	As of April 5, 2022, the third wave of the COVID-19 pandemic is increasingly appearing to subside based on the trend of daily covid cases for 30 days after the peak period of the wave on February 14-28, 2022. From January to April 2022, COVID-19 cases have increased by 1.76 million, with the highest national daily new cases occurred of 64,718 cases	Through a Presidential Decree no. 17/2023 (June 22, 2023), President RI, Joko Widodo, determined that the status of COVID-19 pandemic has ended, and changed the factual status of COVID-19 to an endemic disease in Indonesia. Although covid pandemic has determined ended, but the recovery is still being continued, mainly to

				promote economic development.
Bangladesh	Impacts of Rohingya Refugee Influx on Groundwater System of Cox's Bazar Region in Bangladesh and Potentials for Conflicts.	The main event of influx lasted for about three months. The influx began on 25 August 2017, after the Myanmar Army launched security operations in northern Rakhine state	The main event of influx lasted for about three months. The influx began on 25 August, after the Myanmar Army launched security operations in northern Rakhine state. In September, an average of approximately 14,500 people arrived daily. This dropped to an approximate average of 3,100 arrivals per day in October.	Some aspects of the recovery was completed in **six months** such as setting camps, registering the refugees, providing humanitarian assistance, improvising WASH facilities, setting us Medicare facilities, setting up schools, etc. However, many of these along with other recovery responses, such as avoiding conflicts with local communities, reducing pressure on shared resources such as land, fuel wood and groundwater; increasing resilience to landslide etc are still ongoing.

3.2 Effectiveness of response in immediate aid and return to normalcy

The Indian Ocean tsunami of 2004 highlighted the effectiveness of immediate aid responses. Certain aspects of the return to normalcy occurred relatively quickly, such as the restoration of coastal rail and road networks and the resumption of educational activities. However, other components, including housing reconstruction and the revitalization of businesses, took significantly longer to achieve. In the context of the Fukushima Nuclear Power Station accident, long-term recovery and rebuilding efforts faced challenges in gauging the opinions and consensus of residents. Moreover, assessing public sentiment regarding the reactivation of nuclear power stations proved to be particularly complex.

In instances of Glacial Lake Outburst Floods, the efficacy of response efforts was enhanced by well-coordinated initiatives that involved government agencies, civil societies, and international partners. Effective immediate aid relied on clear communication, logistical support, and resource mobilization. The effectiveness of these response efforts in facilitating a return to normalcy is contingent upon a seamless transition from emergency relief to long-term recovery strategies. Timely assessments, adaptive strategies, and active community participation are vital for achieving sustainable recovery and reconstruction. Moreover, delays in resource allocation, insufficient coordination among stakeholders, and competing priorities can impede the effectiveness of response efforts aimed at supporting community rebuilding and recovery.

During the COVID-19 pandemic in Nepal, the effectiveness of response initiatives in facilitating a return to normalcy similarly depended on an uninterrupted transition from emergency relief to long-term recovery efforts. Essential elements included timely assessments, adaptive strategies, and community engagement, which are critical for sustainable recovery and reconstruction. Delays in resource allocation, inadequate coordination among stakeholders, and

competing priorities posed challenges to the overall effectiveness of response efforts in assisting communities with rebuilding and recovery.

In comparison to other epidemic and endemic conditions, the return to normalcy during the COVID-19 pandemic was protracted due to the novel nature of the disease and the absence of an established cure. Various trial methods were employed, including traditional, Ayurvedic, and allopathic approaches, to address the health crisis. In Indonesia, effective collaboration between the government and local communities demonstrated greater efficacy in response efforts. Although mistrust in government policies and actions occasionally emerged, partnerships with NGOs and civil society organizations gradually fostered trust.

In the Rohingya refugee influx, a multi-tiered response involving government and local communities, NGOs, civil societies, and international organizations effectively provided humanitarian services to a substantial number of individuals.

Overall, all High Impact Low Occurrence (HILO) disasters reported immediate relief efforts from governments, civil society, and the unaffected general public. Nonetheless, it is noted that the return to normalcy often extended over time due to the high-impact nature of these disasters.

3.3 Inequity in the Effects of Disaster: Recovery Among Different Social Groups

In the aftermath of the Indian Ocean tsunami in 2004, the recovery process exhibited significant disparities, largely influenced by political patronage, which facilitated quicker house reconstruction in certain areas. However, tensions arose regarding the distribution of funds, particularly affecting the North and East regions. Business recovery, in contrast, was notably sluggish.

Similarly, during the Fukushima Nuclear Power Station accident, lower-income individuals and families faced considerable disadvantages in their recovery efforts. These groups were less likely to possess financial reserves, insurance coverage, or access to the necessary resources for effective recovery compared to their wealthier counterparts. Additionally, non-Japanese individuals encountered specific challenges, including language barriers, discrimination, and cultural differences, which hindered their access to relief services and participation in decision-making processes.

In the context of Glacial Lake Outburst Floods, rural populations often experienced heightened isolation, limited access to emergency services, and increased food insecurity, alongside disruptions to their livelihoods. Conversely, urban areas typically received more immediate attention and resources due to superior infrastructure and communication facilities. Minority communities faced additional obstacles, such as discrimination, language barriers, and limited representation in decision-making processes, which adversely affected their access to essential resources and services.

During the COVID-19 pandemic, similar patterns were observed in both Nepal and Indonesia, where various socio-economic groups experienced disparate impacts of the pandemic based on their socio-economic backgrounds. Overall, all High Impact Low Occurrence (HILO) disasters highlighted that the nature of the disaster significantly influenced the varying experiences of different socio-economic groups regarding its impacts.

3.4 Impact of post-recovery measures on existing social inequities

The effectiveness of post-recovery measures in addressing social inequities raises critical questions regarding their impact on existing disparities. In the aftermath of the Indian Ocean tsunami in 2004, while numerous aspects of the recovery process aimed to serve all individuals equitably, inequities remained entrenched across various layers of society. Similarly, following the Fukushima Nuclear Power Station accident, disparities between rich and poor, as well as between younger and older populations, persisted. Although public support was directed toward emergency shelters, temporary housing, and the reconstruction of public infrastructure such as roads and bridges, private housing did not receive similar assistance. Consequently, younger individuals tended to migrate away from the community, resulting in an increased proportion of older residents following the recovery phase. In the case of Glacial Lake Outburst Floods, post-recovery measures intended to address existing inequities; however, they often proved inadequate in overcoming the recognized disadvantages faced by certain groups. During the COVID-19 pandemic in Nepal, post-recovery measures demonstrated some effectiveness in mitigating the aforementioned inequities. As the health crisis gradually subsides, attention has shifted toward preparing stimulus measures aimed at fostering economic recovery. This policy brief examines how these stimulus packages can facilitate a recovery that "builds back better," which entails not only restoring economies and livelihoods promptly but also safeguarding the prosperity of minority groups. In Indonesia, recovery efforts primarily focused on alleviating the economic hardships of local populations, with an emphasis on revitalizing community and local economies through collaboration with governmental and community-based organizations. In the context of the Rohingya refugee influx, initial responses centered predominantly on the Rohingya communities; however, subsequent efforts expanded to address the impacts on host communities and to enhance service delivery to local residents.

This analysis suggests that, in most instances, post-disaster recovery measures have contributed to the exacerbation of existing socio-economic disparities within local contexts rather than diminishing them.

3.5 International community’s responses to the HILO disaster event

In response to the Indian Ocean tsunami of 2004, the international community mobilized a range of support measures, including financial assistance, housing reconstruction, and technical expertise. Similarly, during the Fukushima Nuclear Power Station accident, numerous foreign nations dispatched rescue teams to assist in the search for survivors following the earthquake and tsunami. Additionally, the International Atomic Energy Agency (IAEA) deployed teams to investigate the causes of the nuclear accident and to facilitate future reconstruction efforts of the affected facilities. The Kedarnath event, associated with Glacial Lake Outburst Floods, highlighted the importance of international cooperation in disaster response, fostering resilience and solidarity in the face of adversity.

In the context of the COVID-19 pandemic in Nepal, International Non-Governmental Organizations (INGOs) played a pivotal role in developing policy options aimed at supporting recovery from the pandemic's consequences. For example, World Vision International Nepal (WVIN), a child-focused development, humanitarian, and advocacy organization, has been operational in Nepal since 2001. WVIN was also a frontline responder during the response to Nepal's earthquake and has actively participated in addressing the COVID-19 pandemic. This policy brief is intended to complement the efforts of government ministries, donors, United

Nations agencies, INGOs, and other research organizations in evaluating the socio-economic impact of COVID-19. It is based on a review of relevant research papers and reports, as well as on World Vision International's experiences in building back better (BBB) in Nepal and other countries, particularly within the Asia-Pacific region.

In Indonesia, the World Health Organization (WHO), in collaboration with the Food and Agriculture Organization (FAO), the Ministry of Health, and the COVID-19 Task Force, trained data managers on contact tracing procedures. Data managers serve as crucial resources in contact tracing centers, enhancing coordination of COVID-19 contact tracing activities between field operations and national levels, as well as facilitating risk communication and community engagement. The NGO Wahana Visi Indonesia, with support from WHO, conducted virtual Risk Communication and Community Engagement (RCCE) training for health workers in Eastern Indonesia. This training addressed issues such as the stigmatization of COVID-19 patients and healthcare workers, along with strategies to ensure community compliance with health protocols. In the educational sector, UNICEF continued to provide technical support to the Ministry of Education and Culture to enhance response rates by utilizing a RapidPro-based data collection tool that monitors school reopenings in accordance with required safety protocols. By the end of 2020, at least 19,700 schools had commenced face-to-face teaching and learning sessions across Indonesia. The United Nations Development Programme (UNDP) in Indonesia organized its response around three main streams, employing a 'whole of society' approach for prevention and mitigation at both central and local levels. These streams focused on the immediate strengthening of health systems, addressing the socio-economic impact of COVID-19, and promoting innovation and digital solutions. The Government of Indonesia established a COVID-19 Handling Acceleration Task Force to manage the spread of the virus at national, provincial, and district levels.

In the case of the Rohingya refugee influx, large-scale international responses gradually emerged over time. Various agencies and international NGOs actively provided humanitarian services. Countries such as China, Japan, and India engaged in negotiations to facilitate the repatriation of displaced Myanmar nationals to their homeland.

This study demonstrates the active participation of the international community in disaster relief and post-recovery efforts, with the notable exception of the Rohingya refugee influx. Reports indicate that the international response was delayed in this context, primarily due to the complexities of human and social dynamics involved.

3.6 Within-country responses to international responses

In the aftermath of the Indian Ocean tsunami in 2004, the cost of construction surged, not only for tsunami-related reconstruction efforts but also throughout the entire country. This increase was driven by elevated manpower rates, which were supported by the influx of financial resources. Following the Fukushima Nuclear Power Station accident, both national and local communities recognized the importance of collaborative efforts in addressing the challenges posed by the disaster while accepting the international community's support. In the context of Glacial Lake Outburst Floods, the Indian government effectively coordinated relief operations, optimizing rescue efforts and managing the consequences of the disaster. National-level discussions prompted by the event emphasized the need to enhance disaster preparedness and infrastructure resilience, reflecting a proactive stance toward future contingencies. At the local level, affected communities received direct benefits from aid, accessing vital relief supplies and medical assistance that facilitated early recovery and rehabilitation initiatives. Local NGOs and community leaders played

a crucial role in ensuring the equitable distribution of aid and providing on-the-ground support, highlighting the synergy between international assistance and grassroots resilience.

During the COVID-19 pandemic in Nepal, local governments stepped up efforts to support the most vulnerable populations. At the community level, groups such as Aama Samuha (Groups of Mothers in rural areas) effectively communicated information about COVID-19, demonstrating the impact of grassroots social groups. This initiative was entirely voluntary and underscored the importance of community involvement in public health messaging. In Indonesia, the president issued directives to enforce gathering restrictions and large-scale social distancing policies (PSBB) across four provinces and 22 districts/cities. These measures were designed to address the immediate needs of the population, providing social protection measures, ensuring the distribution of personal protective equipment (PPE) and other medical supplies to hospitals treating COVID-19 patients, and delivering aid packages containing basic food items to those facing food insecurity. Additionally, local governments were tasked with surveillance, monitoring, and reporting morbidity and mortality rates related to COVID-19.

In the context of the Rohingya refugee influx, the initial response came from the government and host communities, while the international community's response was delayed. However, various Bangladeshi ministries—including those responsible for Disaster and Relief, Defense, Finance, Foreign Affairs, Home Affairs, and Local Government—collaborated with UNHCR, IOM, UNICEF, and other international and national NGOs to establish a governance mechanism for managing the crisis.

This study illustrates the variability of within-country responses, highlighting the different levels of involvement from national and local governments, NGOs, and grassroots communities in disaster response efforts.

3.7 Effect of HILO disasters on subsequent governance: Centralized or decentralized approach?

In the aftermath of the Indian Ocean tsunami in 2004, the governance response was predominantly centralized. The establishment of the National Council for Disaster Management (NCDM), chaired by the President and comprising representatives from all key ministries, exemplified this centralized approach. Additionally, a Disaster Management Centre was created to facilitate research, warnings, and relief efforts for various disasters. Decision-making regarding tsunami evacuations was also centralized, with the Department of Meteorology responsible for issuing the final recommendations. Despite this centralization, entities such as the National Building Research Organization (NBRO) continued to serve as focal points for specific disaster types, such as landslides, due to their extensive expertise developed over time. Similarly, the governance response to the Fukushima Nuclear Power Station accident was also characterized by centralization. The Japanese government established the Reconstruction Agency and the Nuclear Regulation Authority to manage recovery and regulatory oversight.

Following the Glacial Lake Outburst Floods, there was a notable shift towards decentralized, community-based governance approaches. This evolution emphasized local resilience-building, participatory decision-making, and integrated risk management, aiming to foster inclusive, sustainable, and effective responses to disaster risks in the Himalayan region. Similarly, during the COVID-19 pandemic in Nepal, governance exhibited a decentralized approach. Community groups, such as Aama Samuha (Groups of Mothers in rural areas), played a crucial role in disseminating information about COVID-19, demonstrating the effectiveness of grassroots social organizations. However, in Indonesia, governance at the national level remained centralized, particularly concerning policy formulation and strategic direction. However, regional

levels exhibited some decentralization, allowing for adjustments to policies and strategies to better suit local contexts. In the case of the Rohingya refugee influx, the response was also centralized.

The findings of this study indicate that the Indian Ocean tsunami in 2004, the Fukushima Nuclear Power Station accident, the COVID-19 pandemic in Indonesia, and the Rohingya refugee influx were characterized by a centralized governance approach. In contrast, the responses to the Glacial Lake Outburst Floods and the COVID-19 pandemic in Nepal were more decentralized. Notably, while the Nepalese government adopted a decentralized approach during the COVID-19 pandemic, the Indonesian government maintained a centralized response.

3.8 Effect of HILO disasters on subsequent governance: Securitized or community based?

In the aftermath of the Indian Ocean tsunami in 2004, the response was primarily civilian and voluntary. However, there was significant military involvement in disaster relief activities in certain regions affected by ongoing conflict at that time. The tsunami response in the southern and western parts of the country was predominantly a civilian effort, while military participation was more pronounced in the eastern regions, where conflict was active, and the defense establishment played a critical role in all operational activities, including those involving civilian efforts. In the context of the Fukushima Nuclear Power Station accident, both central and local governments acknowledged the opinions of residents; however, achieving consensus often proved challenging. The Glacial Lake Outburst Floods highlighted the limitations of securitized approaches that prioritize top-down, militarized responses to disasters. In response, subsequent governance strategies emphasized community-based approaches that aimed to foster resilience from the ground up, leveraging local knowledge, capacities, and social networks.

During the COVID-19 pandemic in Nepal, the response shifted towards a more community-based model. In Indonesia, community-based efforts were also encouraged, emphasizing voluntary work; however, these initiatives required assistance from experts. The effectiveness of such community engagement largely depended on the nature of the work and the level of training required.

In the case of the Rohingya refugee influx, the response was characterized by a securitized approach. Bangladesh has established a well-organized disaster response and management system guided by the Standing Order of the Ministry of Disaster Management and Relief. However, the influx of refugees from a different country necessitated adherence to the Geneva Convention on Refugees. Various UN agencies, including UNHCR, IOM, WHO, and UNICEF, collaborated closely with multiple ministries of the Government of Bangladesh. The Office of the Refugee, Relief, and Repatriation under the Ministry of Disaster Management and Relief coordinated all responses on behalf of the Government of Bangladesh. Ministry of Disaster Management and Relief officials were deployed at each camp to oversee camp-level responses. The military was tasked with maintaining security and coordinating emergency humanitarian services, including the creation of a digital database of Rohingyas residing in various camps and the provision of identification cards. Subsequently, other law enforcement agencies assumed responsibility for maintaining law and order while humanitarian services continued to be provided by UN agencies. The findings of this study suggest that the Indian Ocean tsunami, Glacial Lake Outburst Floods, and the Rohingya refugee influx were characterized by securitized responses, whereas the responses to the COVID-19 pandemic in both Nepal and Indonesia were more community-based.

4. Mitigation and resilience measures

4.1 Deployment of technology during and after disaster events

In the aftermath of the Indian Ocean tsunami in 2004, Sri Lankan agencies developed an open-source disaster management software system known as Sahana, which has gained international recognition. A prominent academic in coastal engineering from Sri Lanka played a pivotal role in the establishment of the Indian Ocean Tsunami Warning System, which serves 26 Indian Ocean states. This system incorporates wave-sensing buoys, global telecommunications, and national dissemination mechanisms, including tsunami warning towers. The Disaster Management Centre also functions as the Sri Lankan node for DesInventar, a database dedicated to disaster statistics. Similarly, following the Fukushima Nuclear Power Station accident, technological advancements were made in early warning systems for earthquakes and tsunamis. Additionally, hazard assessments and regulations for incidents beyond the design capacity of the nuclear power station have been enhanced through the implementation of the "defense-in-depth" concept.

In the context of Glacial Lake Outburst Floods, technology proved indispensable in various aspects of disaster response and recovery. Communication infrastructure, such as mobile phones and satellite communications, played a crucial role in facilitating real-time coordination among rescue teams, government agencies, and affected individuals, despite significant damage to physical infrastructure. Social media platforms emerged as powerful tools for disseminating critical information about the disaster, coordinating volunteer efforts, and sharing updates on rescue operations.

During the COVID-19 pandemic in Nepal, the crisis impacted the economy but simultaneously facilitated the expansion of virtual communication. However, challenges remain in the expansion and management of IT infrastructure. Nepal must cultivate innovative and entrepreneurial human resources through multilateral partnerships with various governmental information systems to enhance service delivery. The 14th development plan of Nepal successfully achieved its target of providing internet access to 65 percent of the population, while the 15th plan aims to ensure that 80 percent of Nepalis have internet access by the end of the fiscal year 2023-2024. Significant advancements have been made, including the construction of a nationwide optical fiber network, the implementation of 4G LTE infrastructure, and the establishment of a mobile device management system and national e-payment gateway. Furthermore, the government is exploring the feasibility of utilizing digital signatures for electronic public service delivery. Immediate challenges include the launch of the Sagarmatha Satellite and the rollout of a 5G mobile network.

In Indonesia, information and communication technology (ICT) platforms have been utilized and developed to respond to and prepare for the pandemic. During COVID-19, ICT tools became essential for facilitating interactions, as public gatherings were restricted to maintain social and physical distancing. ICT emerged as a critical technology, enabling social connections, delivering telemedicine services (including data on infections and contact tracing), providing distributed services, and facilitating remote work, virtual education, and business operations. Challenges persist, particularly regarding internet access availability, which is contingent upon ICT infrastructure, as well as the capacity of individuals to utilize these tools effectively.

In the context of the Rohingya refugee influx, initial technology deployment faced deficiencies; however, substantial advancements were made over time. A digital database encompassing all forcibly displaced Myanmar nationals (FDMNs) was established, and photo identification cards were issued to all individuals. UN agencies employed various digital

applications to manage supplies across different locations. Weather stations were installed to provide early warnings, particularly regarding excessive rainfall that could trigger landslides. Additionally, digital telemetering and non-telemetering devices were implemented to continuously monitor groundwater levels and salinity, thereby aiding in the management of groundwater resources.

4.2 Effectiveness of resilience in immediate aid and return to normalcy

The Indian Ocean tsunami of 2004 exemplifies how increased human resilience can enhance immediate assistance and facilitate a return to normalcy. In this disaster, the resilience of affected communities significantly contributed to their capacity for prompt recovery. Conversely, during the Fukushima Nuclear Power Station accident, while the resilience of communities affected by the tsunami was effective in restoring normalcy, certain coastal villages were ultimately relocated to newly developed, elevated areas. In contrast, the resilience strategies employed in response to the nuclear plant accident were less effective, resulting in many local communities failing to return to their original locations.

In the case of Glacial Lake Outburst Floods, strong social networks and local capacities played a crucial role in facilitating effective relief efforts. However, limited resilience, often stemming from socioeconomic vulnerabilities, environmental degradation, or inadequate risk reduction measures, can significantly hinder the effectiveness of immediate aid, particularly in marginalized or remote regions. Resilient communities tend to rebound after disasters by utilizing local resources, traditional knowledge, and adaptive strategies.

In the context of the COVID-19 pandemic in Nepal, several factors contributed to the resilience of the health system and its ability to absorb, adapt, and transform in response to the crisis. These factors, particularly evident at the federal level, included the rapid and comprehensive activation of pre-existing emergency structures and plans, which had yet to be tested within a federalized context. In this newly established federal system, the capacity to formulate response policies was intended to be delegated to local levels, along with the necessary skills and resources for effective policy implementation. However, the novelty of the federal system, compounded by a lack of experience, confusion regarding roles and responsibilities, inadequate local health governance, and limited human, technical, and financial resources, impeded the effective mobilization of these resilience capacities at local levels. Consequently, a rapid response reverted to a pre-federalization, top-down model, overshadowing a more participatory approach that could have strengthened or built upon existing local resilience capacities.

While this approach facilitated absorption strategies to cope with the pandemic, it did not adequately support the adaptive responses of the health system. A robust and flexible command structure is essential for effectively managing emergency situations. Although the federal government plays a critical role in emergency response, there is an imperative need for decentralized frameworks that prioritize the strengthening of local government capacities alongside investments in infrastructure and equipment. Policies that are inclusive, responsive, evidence-based, needs-oriented, and gender-equitable, as well as clear communication strategies, are vital for building resilience to protect population health during emergencies and in the face of evolving health needs. Ongoing learning and adaptation from the COVID-19 pandemic and other acute and chronic shocks to health systems in countries undergoing structural transitions will contribute to long-term resilience building.

Similarly, the Indonesian government implemented an immediate action plan to provide critical assistance and accurate information for rapid relief. However, this effort was significantly

affected by the timely deployment of emergency response teams, the availability of essential supplies (such as food, water, and medical aid), the establishment of temporary hospitals due to limited ward capacity, and a lack of coordination among response teams. In the case of the Rohingya refugee influx, local communities drew upon their experiences from previous influxes, effectively utilizing their knowledge and skills gained from managing earlier situations while living in camps in the area.

4.3 Economic standing as a dimension of resilience helping to face the HILO disaster

In the aftermath of the Indian Ocean tsunami in 2004, affected communities received substantial aid and grants, which played a critical role in their recovery. Following the Fukushima Nuclear Power Station accident, local residents impacted by the tsunami were provided with temporary housing for several years, transitioning from immediate shelters that lasted for months. For those who relocated, new land was allocated in exchange for their previous plots; however, the responsibility for rebuilding their homes rested on their own financial resources. Additionally, evacuees from the areas affected by the nuclear power station accident received compensation funds from Tokyo Electric Power Company (TEPCO). In the context of Glacial Lake Outburst Floods, communities engaged in agriculture, tourism, and small-scale industries demonstrated a greater capacity to cope with the disruptions caused by the disaster. Their ability to diversify livelihood options helped mitigate economic losses. Moreover, household savings, access to credit, and insurance coverage provided a buffer against immediate financial shocks. Recovery efforts, supported by financial resources, facilitated the repair of damaged assets and infrastructure.

During the COVID-19 pandemic in Nepal, the high cost of medicines, such as Hydroxychloroquine, Favipiravir, Remdesivir, and Tocilizumab, meant that individuals with greater financial means were more able to afford necessary treatments. In Indonesia, small and medium-sized enterprises (SMEs) proved to be resilient during the pandemic. A survey analyzing the impact of the pandemic on 25,256 SMEs in Indonesia revealed that approximately half of these businesses were able to withstand the challenges posed by the crisis. The changes in the business environment prompted many SMEs to explore new opportunities and implement mitigation strategies to survive the rapidly changing conditions, such as pivoting to food delivery services and offering frozen food products in response to social distancing measures and restrictions on gatherings. In the case of the Rohingya refugee influx, initial government budget allocations were limited due to the country's relatively weak economy. However, the pressure on the national economy was alleviated by the influx of aid from other countries and international agencies.
The findings of this study underscore the significance of economic resilience in effectively addressing the challenges posed by High Impact Low Occurrence (HILO) disasters.

4.4 Social capital as a dimension of resilience helping to face the HILO disaster

In the aftermath of the Indian Ocean tsunami in 2004, social capital played a significant role, particularly within the affected communities. Following the Fukushima Nuclear Power Station accident in 2011, the government implemented measures to facilitate the rebuilding of coastal areas, including a temporary increase in income tax by 2.1% for a duration of 25 years. Additionally, salaries for government employees, including university professors, were reduced by 10% for several years as part of the recovery efforts. In the context of Glacial Lake Outburst Floods, strong social ties and mutual support networks within communities were instrumental in enabling collective response and recovery efforts. Informal networks comprising kinship ties,

neighbourhood associations, and community-based organizations played a crucial role in delivering immediate assistance and emotional support. High levels of trust among community members, as well as with external stakeholders such as NGOs, fostered effective coordination and collaboration during disaster response and recovery activities. The bonds within the community and the presence of organized groups facilitated quicker emergency responses and rebuilding initiatives.

During the COVID-19 pandemic in Nepal, social capital also contributed to resilience efforts, albeit to a lesser extent. In Indonesia, a notable example of social capital in action occurred in the city of Blitar, where voluntary cooperation among government entities and local residents was essential in navigating the crisis. This collaboration involved local government officials, a COVID-19 task force, volunteers from the neighbourhood, and various city communities. The key to success lay in maintaining mutual trust, which strengthened cooperation and enhanced cross-stakeholder communication. While public compliance with social mobility restrictions and adherence to health protocols was not universal, a general sense of social solidarity emerged in addressing the COVID-19 crisis. In the context of the Rohingya refugee influx, the resilience of the Bangladeshi people was evident, as they demonstrated a commitment to supporting those in need with whatever resources they could offer.

4.5 Religious/ cultural factors as dimensions of resilience helping to face the disaster

Certain religious and cultural factors significantly contributed to the recovery and resilience processes following the Indian Ocean tsunami in 2004. In contrast, during the Fukushima Nuclear Power Station accident, religion and culture had minimal influence in Japan. Local residents generally expressed a desire to return to their original locations; however, the radiation from the nuclear power station precluded their return, leading many individuals, particularly younger generations, to decide against coming back.

In the case of the Glacial Lake Outburst Floods, cultural beliefs, practices, and traditions provided a sense of identity and continuity during the crisis. Religious institutions and spiritual leaders played a pivotal role by offering solace, moral support, and organizing community rituals or ceremonies aimed at promoting healing. Additionally, traditional knowledge, indigenous practices, and ecology-based adaptive strategies contributed to resilience through sustainable land use practices and effective resource management. During the COVID-19 pandemic in Nepal, religious and cultural dimensions did not pose significant challenges. However, the economic impact was notable, with the pandemic shaving approximately 0.13% off the gross domestic product (GDP) and resulting in the loss of around 15,880 jobs. In Indonesia, the role of religion in disaster risk governance proved effective, particularly during times of crisis. Faith-Based Organizations (FBOs) were instrumental in correlating sacred religious doctrines with the practical challenges of human life, thereby facilitating sustainable actions in disaster governance, including efforts to mitigate the adverse effects of the COVID-19 pandemic. FBOs demonstrated their capacity to collaborate across non-state sectors and played a multidimensional role in mobilizing their members to adhere to government policies and participate in mitigation efforts. During the pandemic, FBOs actively engaged communities in overcoming crises through leadership, organizational strategies, and theological doctrines. In the context of the Rohingya refugee influx, religious affiliations were significant, as the Rohingyas are predominantly Muslims. The majority of residents in the Cox’s Bazar area felt a sense of "religious obligation" to support those in distress from the same faith. According to the findings of this study, all High Impact Low Occurrence

(HILO) disasters examined, with the exception of the Fukushima Nuclear Power Station accident, indicated the presence of cultural and religious factors associated with resilience patterns.

4.6 The level of investment made by governments for future resilience

In the aftermath of the Indian Ocean tsunami in 2004, the introduction of a "Buffer Zone" was implemented, with a designated width of 100 meters on the west coast and 200 meters on the east coast. This zone was subsequently reduced to between 35 and 120 meters by the Coast Conservation Department, based on data regarding coastal erosion. Following the Fukushima Nuclear Power Station accident, the Japanese government allocated substantial funds for reconstruction and disaster preparedness. This investment included rebuilding critical infrastructure, relocating towns to safer areas, and enhancing public facilities to meet higher seismic standards. In response to Glacial Lake Outburst Floods, governments at the national, state, and local levels dedicated financial resources to bolster disaster preparedness, response, and recovery capabilities. Investments were made in early warning systems, emergency response infrastructure, and capacity building for disaster management agencies.

During the COVID-19 pandemic in Nepal, a Preparedness and Response Plan (NPRP) was developed in collaboration with the United Nations in April 2020. The strategic pillars for Nepal from 2020 to 2025 were established by the Birat Medical Health Trust. In Indonesia, to mitigate the economic impacts of the COVID-19 pandemic, the government initiated the National Economy Recovery Program (PEN). This program was a direct response to the significant economic challenges posed by social activity restrictions, particularly affecting informal sectors and small and medium-sized enterprises (SMEs). The budget allocated to SMEs constituted the largest share, as the primary objective of PEN was to enhance the productivity of SMEs and maintain their economic contributions. SMEs represent a vital sector in Indonesia, employing a substantial portion of the workforce. Due to decreased demand, many SMEs halted production, prompting the government to allocate 35.11% of the budget specifically for their support. Various programs were established to assist SMEs through financing incentives and corporate tax relief. In the context of the Rohingya refugee influx, investments gradually increased with international support. Given the unpredictable nature of this event, future planning proved challenging. Nevertheless, actions were taken to alleviate pressure on natural resources and the environment, thereby mitigating the impacts on host communities. The Government of Bangladesh (GoB) sought to mobilize support from the United Nations and other nations to exert pressure on the Government of Myanmar (GoM) to take actions that would prevent future mass exoduses and facilitate the safe return of forcibly displaced Myanmar nationals (FDMNs) to their homeland. The findings of this study indicate the varying levels of investment made by governments, from national to grassroots levels, in developing mechanisms aimed at building future resilience in relation to particular HILO disaster.

4.7 The level of investment made by communities for future resilience

In the aftermath of the Indian Ocean tsunami in 2004, reconstruction efforts utilized permanent materials, such as masonry, rather than temporary solutions like timber boarding. Following the Fukushima Nuclear Power Station accident, local communities received support from the government to aid their recovery. In the context of Glacial Lake Outburst Floods, communities mobilized resources and engaged in self-help initiatives aimed at enhancing resilience to future disasters. These efforts included investments in local infrastructure upgrades, such as flood

protection measures and community shelters, as well as the establishment of community emergency response teams and the cultivation of social networks for mutual support. Communities also focused on capacity building to improve disaster response capabilities through training programs, awareness campaigns, and participatory risk assessments. Investments were made to develop local skills and knowledge essential for effective disaster preparedness and response.

During the COVID-19 pandemic in Nepal, a few hospitals began offering free or nominally priced services, with support primarily coming from Non-Resident Nepalis (NRNs).
In Indonesia, communities mobilized resources and engaged in self-help initiatives to bolster resilience in their neighbourhoods, which included the establishment of community emergency response teams and the fostering of social support networks. In the case of the Rohingya refugee influx, community investments gradually diminished.

With the exceptions of the Fukushima Nuclear Power Station accident and Rohingya refugee influx, all other High Impact Low Occurrence (HILO) disasters examined in this study reported various community-driven investments.

4.8 The level of investment made by business for future resilience

In the aftermath of the Indian Ocean tsunami in 2004, large businesses diversified their operations as a risk mitigation strategy; however, small businesses did not adopt similar measures. Following the Fukushima Nuclear Power Station accident, businesses invested in enhancing infrastructure resilience by retrofitting buildings to better withstand earthquakes and tsunamis, improving business continuity plans, and purchasing disaster insurance to mitigate financial risks associated with future disasters. In the context of Glacial Lake Outburst Floods, businesses focused on developing business continuity plans to reduce disruptions caused by disasters and ensure the continuity of operations. This included investments in redundant systems, enhancing supply chain resilience, and providing workforce training. Additionally, businesses sought insurance coverage and implemented risk transfer mechanisms to protect against financial losses related to disasters. These investments in risk management strategies aimed to enhance overall business resilience and facilitate rapid recovery.

During the COVID-19 pandemic in Nepal, some businesses began to offer assistance to varying degrees. In Indonesia, the pandemic resulted in a decline in investment, which in turn exacerbated unemployment rates. Nevertheless, the value of foreign investment in the health and social work sector showed no significant change between the three-year period preceding the COVID-19 pandemic and the three-year period during the pandemic. The average growth rate of investment during the pre-pandemic period was 74.42%, which was notably higher than the 34.75% growth rate observed during the pandemic. Recovery within the health sector must be prioritized as a critical component of overall recovery efforts, focusing on strengthening the national health system to enhance resilience in the face of health emergencies and promoting self-sufficiency. Furthermore, revitalizing micro, small, and medium-sized enterprises (MSMEs) and sectors that provide significant local employment should be supported through incentives and the creation of a favourable business environment.

In the case of the Rohingya refugee influx, business investments gradually diminished. With the exceptions of the Fukushima Nuclear Power Station accident and the Rohingya refugee influx, all other High Impact Low Occurrence (HILO) disasters examined in this study indicated various business investments.

4.9 The level of investment made by individuals for future resilience

In the aftermath of the Indian Ocean tsunami in 2004, individuals made investments in their personal preparedness to a certain extent. Following the Fukushima Nuclear Power Station accident, individuals were continually reminded of the risks posed by frequent natural disasters and thus were better prepared for potential future events. During the Glacial Lake Outburst Floods, individuals took proactive measures for personal preparedness, which included purchasing emergency supplies, securing insurance coverage, and retrofitting their homes to withstand hazards. Furthermore, individuals contributed to community-based resilience initiatives by volunteering, participating in neighbourhood associations, and providing financial or in-kind support for local resilience-building efforts.

During the COVID-19 pandemic in Nepal, healthcare professionals, including doctors, nurses, and other health workers, were among the first to offer voluntary support and assistance. However, it is important to note that some business individuals profited during the pandemic by selling goods at inflated prices. In Indonesia, individuals typically supported and contributed to community efforts by volunteering and participating in local resilience-building initiatives. In the context of the Rohingya refugee influx, individual contributions gradually diminished and eventually ceased. With the exception of the Rohingya refugee influx, all other High Impact Low Occurrence (HILO) disasters examined in this study reported instances of individual investments that sometimes led to community-based resilience initiatives.

4.10 Was the nature and level of investment limited due to the HILO nature of the disaster?

In the aftermath of the Indian Ocean tsunami in 2004, the nature and level of investment were indeed limited due to the High Impact Low Occurrence (HILO) nature of the disaster. Conversely, in the case of the Fukushima Nuclear Power Station accident, this was not the case. Earthquake and tsunami disasters are relatively frequent in Japan, though their impacts are generally not as severe as those experienced during the 2011 Great East Japan Earthquake (GEJE). The significant impact of nuclear power station accidents is well recognized, resulting in substantial investments aimed at mitigating future risks. Regarding the Glacial Lake Outburst Floods, the level of investment for future resilience reflected a multi-stakeholder approach that included contributions from governments, communities, businesses, and individuals. During the COVID-19 pandemic in Nepal, various stakeholders, including the government, private sector entities, and Non-Resident Nepalis (NRNs), played a crucial role in providing support. In Indonesia, most investments in the health sector were directed towards recovery efforts and the eradication of the virus, focusing on initiatives such as vaccines, integrated public health services, the BPJS health insurance program, and related research and development. Additionally, preparations were made to address the potential emergence of new pandemic waves. In the context of the Rohingya refugee influx, the Government of Bangladesh (GoB) faced economic constraints that limited its ability to invest in the provision of necessary services. Initial investments were primarily focused on meeting basic humanitarian needs. However, subsequent investments aimed to improve living conditions within the overcrowded camps. For instance, shallow, vulnerable hand-pumped wells were replaced with a centralized piped water system, and dedicated facilities were developed in specific locations to enhance the living conditions of forcibly displaced Myanmar nationals (FDMNs).

It can be argued that, with the exception of the nuclear power station accident, the other HILO disasters examined in this research encountered difficulties in securing adequate investments due to their HILO nature.

4.11 Did the investment for a future HILO disaster also provide benefits (or detriments) for everyday life?

In the aftermath of the Indian Ocean tsunami in 2004, investments aimed at preparing for future High Impact Low Occurrence (HILO) disasters did indeed yield benefits for everyday life. Following the Fukushima Nuclear Power Station accident, investments contributed to safety and security in daily life while also generating economic benefits, thereby strengthening cooperation and social cohesion throughout the community. In the case of the Glacial Lake Outburst Floods, investments in resilience-building measures for potential future HILO disasters, such as the 2013 Kedarnath GLOF, provided broader advantages beyond mere disaster preparedness and response in the Himalayan region. These investments often enhanced everyday life and promoted sustainable development in various ways. During the COVID-19 pandemic in Nepal, the focus remained primarily on disaster preparedness, with less emphasis on immediate benefits to everyday life. Conversely, in Indonesia, investments in health services and research and development (R&D) in the health sector did bring about positive outcomes for daily living. In the context of the Rohingya refugee influx, dedicated facilities such as housing blocks, water, sanitation, and hygiene (WASH) facilities, and a distributed water network provided significant benefits for all residents. Additionally, improvements to national and regional highways, as well as local roads, enhanced connectivity and facilitated easier travel.

Overall, the findings indicate that investments made in preparation for future HILO disasters have consistently resulted in benefits for everyday life across various contexts.

4.12 Did the investment constitute a “build back better” scenario for the majority?

In the aftermath of the Indian Ocean tsunami in 2004, many houses were rebuilt to higher standards; however, some structures were constructed to inferior standards due to the urgency of the reconstruction process and inadequate supervision. Notably, houses overseen by international NGOs incorporated more robust features, such as concrete columns at each corner. There is evidence that post-tsunami reconstruction included the construction of two- and three-story school buildings designed with three parallel rows of columns instead of the conventional two. Following the Fukushima Nuclear Power Station accident, investments were aligned with a "Build Back Better" philosophy. These investments aimed to strengthen communities and economies after disasters while also fostering a more sustainable and secure environment for the future. In the context of the Glacial Lake Outburst Floods, investments in rebuilding infrastructure—such as roads, bridges, ropeways, and utilities—often integrated resilient design principles to enhance their capacity to withstand future disasters. Reconstruction efforts focused on modernizing and improving infrastructure systems, thereby benefiting the majority of the population and contributing to enhanced connectivity, increased economic activity, and an overall improvement in quality of life.

During the COVID-19 pandemic in Nepal and Indonesia, investments indeed constituted a “Build Back Better” scenario for the majority. Similarly, in the case of the Rohingya refugee influx, initial makeshift shelters were situated in precarious locations vulnerable to disasters such as landslides. Additionally, shallow hand-pumped wells were at risk of pollution and drying out during the dry season, while makeshift WASH facilities posed significant risks of microbiological contamination of shallow groundwater. The practice of cooking with firewood collected from surrounding reserve forests resulted in extensive deforestation. Subsequent investments included

the construction of landslide protection measures, the installation of a piped water system utilizing groundwater sourced from deeper layers, and the provision of kitchen blocks equipped with LPG cylinders. These initiatives collectively improved environmental conditions and reduced vulnerability.

The findings of this study indicate that investments constituted a "Build Back Better" scenario for the majority in all HILO disasters examined.

4.13 Did the investment constitute a "build back better" scenario for the most 'vulnerable' in society?

In the aftermath of the Indian Ocean tsunami in 2004, some coastal fisher families were relocated further inland to structures of better quality, encompassing both single- and multi-story buildings. However, in certain instances, these families chose to rent out their new accommodations and return to their rudimentary coastal dwellings, as these locations afforded greater ease for their fishing activities. This suggests that livelihoods may hold greater importance for the most vulnerable populations than risk mitigation measures. Furthermore, some hotel buildings and police stations, reconstructed with Japanese aid on the southwest coast, featured wall-free ground floors, which served as parking areas for police stations. This design can be interpreted as a proactive response to potential future tsunami threats. In the case of the Fukushima Nuclear Power Station accident, some elderly individuals, lacking successors and adequate financial reserves, opted not to return to their previous lives. Regarding the Glacial Lake Outburst Floods, targeted investments in resilience-building initiatives prioritized the needs of the most vulnerable populations, including marginalized communities, women, children, the elderly, and persons with disabilities.

During the COVID-19 pandemic in Nepal, the National Planning Commission (NPC) commissioned a study to assess the socio-economic impacts of the pandemic. The NPC sought feedback and recommendations from key sectors and development partners, including International Non-Governmental Organizations (INGOs), to inform the design and development of policy options aimed at facilitating recovery from the consequences of COVID-19. In Indonesia, it remains unclear whether investments constituted a "Build Back Better" scenario for the most vulnerable segments of society. Conversely, in the context of the Rohingya refugee influx, investments did support a "Build Back Better" scenario for the most vulnerable populations.

The findings of this study indicate a mixture of both benefits and disadvantages for vulnerable communities arising from the broader investments associated with the "Build Back Better" recovery and reconstruction initiatives.

4.14 What measures, if any, were adopted to keep the HILO disaster in public consciousness?

In the aftermath of the Indian Ocean tsunami in 2004, tsunami memorials were established in Yala, a popular wildlife resort, and in Peraliya, near Hikkaduwa, where a train disaster resulted in approximately 2,000 fatalities. Annually, the public is encouraged to observe a two-minute silence from 9:25 to 9:27 AM to commemorate the victims of the tsunami. Following the Fukushima Nuclear Power Station accident, disaster education emerged as one of the most effective measures for raising awareness. While most individuals may experience one or two tsunamis in their lifetime, nuclear power station accidents are significantly rarer. Therefore, the lessons learned from past disasters should be imparted to future generations, thereby contributing to efforts aimed at

reducing the likelihood of similar incidents. In the context of Glacial Lake Outburst Floods, measures were frequently adopted after significant events, such as the 2013 Kedarnath GLOF, to maintain public awareness regarding the risks associated with such disasters and to promote long-term resilience strategies.

During the COVID-19 pandemic in Nepal, earthquake preparedness was taught in schools but unfortunately had unintended negative consequences for children. Students were instructed to hide under tables or beds during earthquakes; however, when a disaster occurred, children playing outside returned home to seek shelter as they had been taught, which tragically led to fatalities. To address this, it is essential to implement stage dramas in rural areas and utilize adequate radio and television broadcasts to educate children and the public. Additionally, parents should be informed about HILO disasters to ensure comprehensive awareness. In Indonesia, regular dissemination of information and communication to the public is vital, utilizing various tools and social media platforms to ensure timely and frequent updates.

In the context of the Rohingya refugee influx, one of the measures adopted was the construction of improved facilities for local communities alongside forcibly displaced Myanmar nationals (FDMNs). Local government institutions have also been engaged in fostering better relationships and mitigating tensions between host communities and FDMNs. Rather than solely utilizing international aid for FDMNs, investments have been directed toward enhancing the living conditions of local residents.

References

Rapport, F. (2010). Summative analysis: A qualitative method for social science and health research. *International Journal of Qualitative Methods*, *9*(3), 270-290.

Annex 3 – Workshop Agenda

RESILIENCE TO HIGH IMPACT LOW OCCURRENCE (HILO) DISASTERS: A CROSS-SECTOR COMPARISON

National Academy of Sciences of Sri Lanka

COLOMBO HILTON RESIDENCIES (UNION PLACE, COLOMBO 2)
5th-7th September 2024

aassa THE ASSOCIATION OF ACADEMIES AND SOCIETIES OF SCIENCES IN Asia

Meeting Agenda

5th September 2024

5:30 pm-9:00 pm: Inauguration

5:30 pm	Welcome Drink and Registration
6:00 pm	Welcome address
	Professor Ajit Abeysekera, President, NASSL
6:05 pm	Address by Dr Ananda Mallawatantri
	Advisor to H.E. the President
6:15 pm	Address by President, AASSA
	Professor Nuri Yurdusev
6:20 pm	Address by Coordinator, IAP
	Dr Peter McGrath
6:30 pm	Keynote Speech
	Professor Sonali Deraniyagala
	Economic Impacts of High Impact Low Occurrence (HILO) Disasters
7:30 pm	Preview of Cross-sector Analysis
	Professor Udayangani Kulatunge (on behalf of NASSL)
7:40 pm	Vote of Thanks
	Professor Sagarika Ekanayake, General Secretary, NASSL
7:45 pm	Fellowship and Dinner

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Meeting Agenda

6th September 2024

8:30am-12:30pm: Keynote Addresses

8:30 am	*Coffee and Conversation*
9:00 am	Professor Dilanthi Amaratunge **Comparison Between Natural HILO Hazard (Tsunami) and Biological HILO Hazard (COVID)**
10:00 am	*Morning Tea/ Coffee Break*
10:30 am	Dr Senaka Basnayake **Disaster Management and Mitigation in Asia**
11:30 am	Professor Udayangani Kulatunge **Cross Sector Comparison of HILO Disasters Based on Country Reports**
12:30 pm	*Lunch*

1:30 pm- 5:00 pm: Country Presentations on HILO Disasters

1:30 pm	**Rohingya Refugees Influx into Cox's Bazaar in Bangladesh** Dr Kazi Matin Ahmed
2:00 pm	**2004 Indian Ocean Tsunami in Sri Lanka** Professor Priyan Dias
2:30 pm	**2011 Tohoku Earthquake, Tsunami; plus Fukushima Disaster in Japan** Professor Kenji Satake
3:00 pm	**2013 Kedarnath Glacier Lake Outburst Flood in India** Dr Kalachand Sain
3:30 pm	*Afternoon Tea/Coffee Break*
4:00 pm	**COVID-19 Pandemic in Nepal** Professor Anjana Singh
4:30 pm	**COVID-19 from Indonesian Perspective** Dr Finarya Legoh
5:00 pm	End of day's proceedings

RESILIENCE TO HIGH IMPACT LOW OCCURRENCE (HILO) DISASTERS: A CROSS-SECTOR COMPARISON

National Academy of Sciences of Sri Lanka

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aassa THE ASSOCIATION OF ACADEMIES AND SOCIETIES OF SCIENCES IN Asia

Meeting Agenda

7th September 2024

8:30 am-12:30 pm: Feedback

8:30 am	*Coffee and conversation*
9:00 am	**Structured participant discussions on cross-sector comparison**
10:00 am	*Morning Tea/ Coffee Break*
10:30 am	**Participant feedback on cross-sector comparison / Discussion on statement**
12:00 noon	*Lunch*

End of Programme

Annex 4 – Workshop Participants

Attendance for the HILO conference. 5th to 7th September 2024

Agency	Name	Thu 5th	Fri 6th	Sat 7th
Science Council of Japan	Prof Kenji Satake	1	1	1
Bangladesh Academy of Sciences	Dr. Kazi Matin Uddin Ahmed	0	0	0
Nepal Academy of Science and Technology	Prof Anjana Singh	1	1	1
Indian National Science Academy	Dr. Kalachand Sain	1	1	1
Indonesian Academy of Sciences	Ms Finarya Legoh	1	1	1
ADPC (Asian Disaster Prepardness Centre)	Dr.Senaka Basnayake	1	1	1
AASSA	Prof Nuri Yurdusev	1	1	1
AASSA	Ms Hanseul Kim	1	1	1
Turkish Ambassador to Sri Lanka	HE Semin Turgut	1	0	0
NASSL	Prof Priyan Dias	1	1	1
NASSL	Prof Ajit Abeysekera	1	1	1
NASSL	Prof Saroj Jayasinghe	1	1	1
NASSL	Dr Ranjit Mahindapala	1	0	0
NASSL	Prof Udayangani Kulatunga	1	1	1
NASSL	Dr Unnathi Samaraweera	1	1	1
NASSL	Prof. Malik Ranasinghe	0	0	0
NASSL	Prof. Sagarika Ekanayake	1	1	1
NASSL	Dr. A.M. Mubarak	1	0	0
NASSL	Prof. Rahula Attalage	0	0	0
NASSL	Prof. Preethi Udagama	0	0	0
NASSL	Prof. Rupika Rajakaruna	0	0	0
NASSL	Dr. Locana Gunaratna	1	1	1
SLAYS	Dr Nimshi Fernando	0	1	1
YPL	Prof Kosala Weerakoon	0	1	1
NSF	Dr Ranjith Senaratne	1	0	0
NSF	Ms. Christine Dassanayake	0	1	1
DMC	Maj Gen Udaya Herath	0	0	0
DMC	Maj Gen Udaya Herath	0	0	0
DMC	Maj Gen Udaya Herath	0	0	0
NBRO	Dr Asiri Karunawardena	1	0	0
NBRO	Mr. Chinthaka Rathnasiri	1	1	0
NBRO	Ms. Dilushi Siriwardana	1	1	1
UCMB	Prof Siri Hettige	0	0	0
UCMB	Prof Nishara Fernando	0	1	0
Secretariat	Dr Ananda Mallawathanthri	1	0	0
University of Moratuwa	Dr Menaha Thayaparan	0	0	0
University of Moratuwa	Dr Chathura De Silva	1	1	0
University of Peradeniya	Prof. Ranjith Dissanayake	0	0	0
UDA (Urban Development Authority)	Mr. Nimesh Herath	0	0	0
UDA (Urban Development Authority)	Kusala Mahalekame	0	1	0
UDA (Urban Development Authority)	Ms. Chandana Kalupahana	0	1	0

CEA (Central Environment Authority)	Mr. P.B Hemantha Jayasinghe	0	0	0
Department of Meteorology	Ms. A.R. Warnasooriya	0	0	0
IPS (Institute of Policy Studies of Sri Lanka)	Dr. Dushni Weerakoon	0	0	0
IPS (Institute of Policy Studies of Sri Lanka)	Dr. Nisha Arunatilake	0	0	0
Federation of Sri Lanka (LGA)	Ms Hemanthi Goonasekera	0	0	0
ADPC (Asian Disaster Prepardness Centre)	Mr. N.M.S.I. Arambepola	0	1	0
Sevanatha	H.M.U.Chularathna	0	0	0
UNICEF	Watsala Jayamanna	0	0	0
Sri Lanka Red Cross Society (SLRCS)	Dr. Mahesh Gunasekara	0	0	0
CEO Climate Change Secretariat	Dr Anil Jasinghe	0	0	0
SA Network for Disaster Mitigation	Ramona Miranda	1	1	1
NASTEC	Seyed Shahmy	0	0	0
NASTEC	Ms. Thilini Munagamage,	0	1	0
NASTEC	Ms. Rasitha Perera:	0	0	0
NASTEC	Ms. Sajini Dickmadugoda,	0	1	0
Ministry of Health	Dr. Novil Wijesekara	0	0	0
UNDP	Mr. Vajira Hettige	0	0	0
World Vision	Mr. Winson Gnanatheepan	0	0	0
UN	Ms. Wagisha Perera	0	0	0
Center for Environment Development	Mr. Uchita de Zoysa	1	1	1
Verite Research	Dr Nishan de Mel	0	0	0
Verite Research	Portia Kemps and	0	0	0
Verite Research	Isurika Perera	0	0	0
Institute for Health Policy	Dr Ravi Ranan-Eliya	0	0	0
South Eastern University	Dr Ajith Thamboo	0	1	0
NASSL	Priyanga Opatha	1	1	1
	TOTAL PARTICIPANTS	**26**	**30**	**21**

Annex 5 – Structured Participant Feedback

Categories (for Analysis)

1. Type of HILOs ('Natural' vs. Human-made, Biological, Sociological) and how HILOs are defined.
2. Socio-economic, environmental, governmental, vulnerability, and educational conditions of the country.
3. Scientific Data: What is the level of use of scientific data? How was data used or not used?
4. How do governments respond to HILOs?
5. Balance of responsibility between the government, donors, other stakeholders, and the public.
6. The anthropogenic dimension of HILOs: There are historical root causes of HILOs.
7. Post-disaster unforeseen issues.
8. Local/indigenous knowledge regarding HILOs.
9. Pre-, during, and post-HILO disaster contexts (including preparedness and responses).
10. Recovery and mitigation.

Lessons (from Events)

1. Natural and human-made disasters are more context- and environment-specific. Post-Disaster Needs Assessments (PDNAs) are conducted for these types of disasters. In contrast, biological disasters are more globalized, and no such PDNAs are being conducted.
2. Policy incoherence (country specialists can provide further comments on this point) and institutional incoherence.
3. The non-availability of a proper updated government database on HILOs.
4. Lack of awareness among the general public, experts, and the government regarding HILOs.
5. The absence of investment plans for HILOs.
6. Insufficient preparedness, the absence of existing contingency plans, and the oversight of ethical plans.
7. The need to establish a centralized entity for HILO disasters.
8. Reporting unusual behaviors of animals and any other unusual phenomena.
9. Establishing trust among the general public during HILO disasters.
10. A roadmap with a timeline indicating very specific details, such as task-based evacuation locations (as established in Bangladesh), including evacuation routes.

Strategies (for Resilience)

1. Workshops (educating different stakeholder groups at various levels).
2. Encouraging public-private partnerships.
3. Climate adaptation measures, such as risk transfer measures: insurance, resettlement, etc.
4. Climate reinsurance: Without reinsurance, it is difficult to address HILOs. DFCC, the Green Climate Fund, and researchers encourage bankers to shift towards blended financing.
5. Sufficient budgetary allocations as financial support and important fixed assets.
6. Structural measures: Developing proper building codes
7. Non-structural measures: Establishing effective early warning systems, implementing cost-effective measures, and conducting drills at designated times. (Depending on the type of HILO, the measures that should be taken differ. Therefore, both structural and non-structural measures should be implemented accordingly.)
8. Multi-purpose buildings for all types of HILO disasters.
9. Public awareness and education.
10. Having a pre-designed recovery plan.

Annex 6 – Video Script

Building Resilience against HILO Disasters (Script & Video Timeline)

https://nassl.org/resilience-to-high-impact-low-occurrence-hilo-disasters-a-cross-sector-comparison/

Duration	Visual	Voice
00:10	Opening animation Video Title "**Building Resilience against HILO Disasters**"	
00:25	General pictures of the environment followed by natural disaster visuals	***Narration***: From the beginning of time humans have faced many challenges in their environment. Climactic changes and natural phenomena like hurricanes, earthquakes, volcanic eruptions and wildfires have caused serious disruption to human communities. Human existence depends on how best they can meet these challenges and adapt their lifestyles to suit the environments that they are in.
00:55	General pictures of medical emergency, hospital visuals followed by natural disaster visuals On-screen Text "High Impact Low Occurrence"	***Narration***: The challenges that humans face aren't always caused by natural triggers. Pandemics, for example, are caused by biological events while socio political events such as wars and revolutions can also have a great impact on society. Since the Covid 19 pandemic, there has been a renewed focus on the hazards we face and how societies can reduce the risks associated with these hazards and recover from them faster and better. In general, most governments and policy makers are aware of hazards that occur frequently and plans to mitigate their effects have been developed. However, some hazards which occur more sporadically can have a greater impact on human community. Ignoring these High Impact Low Occurrence hazards, known as HILO events, can be disastrous with repercussions affecting many generations.
00:25	Conference Title slide followed by visuals of the conference (Head table, 2-3 key speakers and crowd visuals)	***Narration***: Recently, the National Academy of Sciences of Sri Lanka organized a conference to discuss ways in which we can improve Resilience against High Impact Low Occurrence Disasters. This conference brought together experts, policy makers and practitioners from East and South Asia

		to reflect on recent HILO disasters and share learnings across countries on how best to prepare for these events.
00:35	Dr Basnayake visuals with "Number of Disasters by Continent slide" + "Number of deaths by disaster type slide"	***Narration***: Speaking at the conference, Dr. Senaka Basnayake of the Asian Disaster Preparedness Center, noted that the frequency and intensity of hazards have been increasing in the past few years. This has led to greater loss of lives and livelihoods and societies have been struggling to cope with the aftermath of these events. This has prompted a change of approach with greater recognition on the need to move from a purely disaster management approach to a more coordinated disaster prevention and risk reduction approach.
00:20	"DRR components" slide	***Narration***: The Disaster Risk Reduction process begins with the preparation stage where disaster vulnerabilities are identified and addressed. There are many factors that influence the preparedness of a society to face future hazards. However, the infrequent nature of HILO events presents a particularly significant challenge.
00:40 (01:06:16-01:06:58) Day 2 / TIIKM J Hilton Day 2 3	Prof. Kulatunga speaking with "preparedness" slide + Name & Title band **"Professor Udayangani Kulatunga"** **Professor in Building Economics, University of Moratuwa, Sri Lanka**	***Professor Udayangani Kulatunga:*** *"Because of the infrequent occurrence the awareness and the experience regarding the previous occurrences were very rare. For example, if we take Sri Lanka, awareness regarding… ~~Covid sorry…~~ tsunami was not there whereas in the Japanese context, the awareness was there. ~~Emm~~ And then because of the infrequent nature, uncertainty of the event, it's very difficult for us to predict them, and also because of the infrequent nature, prioritizing other short-term goals rather than investing more on the HILO disasters were evident.*
00:30	UNESCO IOC logo or slide from Professor Dilanthi Amaratunga's powerpoint	***Narration***: Learning from past disasters is crucial to help mitigate the effects of a hazard and prevent it from becoming a disaster. After the Indian Ocean Tsunami in 2004, the Inter-governmental Oceanographic Commission of UNESCO developed an exercise to assist governments to assess their level of preparedness to face a tsunami. This is known as the IOWave or Indian Ocean Wave Tsunami Exercise.

00:40 (22:00 - 22:40) Day 2/TIIKM J Hilton Day 2 2	Professor Dilanthi Amaratunga speaking + powerpoint slide Name & Title band **"Professor Dilanthi Amaratunga"** **Professor of Disaster Risk Reduction and Management, Global Disaster Resilience Centre, University of Huddersfield, UK**	***Professor Dilanthi Amaratunga:*** *What it does is, every 2 years they actually sort of put all Indian Ocean countries on a artificially generated tsunami wave and get all the countries to sort of test their capabilities, just to sort of see how prepared they are. So this is a very very important exercise. It actually helps the countries to test their potential in terms of operationalize of communications and to review their emergency response standard operating procedures and also to promote emergency and community preparedness.*
00:20	Medical emergency + hospital visuals	***Narration***: The need to develop plans to mitigate risks associated with biological hazards has also received a boost since the Covid 19 pandemic. Many countries have developed plans at the national level but planning at sub national levels is often inadequate or outdated and greater attention needs to be paid to this area.
00:10	Same as above	***Narration***: An important aspect to consider when developing plans to mitigate the effects of hazards is to recognize that hazards do not always happen in isolation.
00:40 (36:11 - 36:51) Day 2/TIIKM J Hilton Day 2 2	Professor Dilanthi Amaratunga speaking + powerpoint slide Name & Title band **"Professor Dilanthi Amaratunga"** **Professor of Disaster Risk Reduction and Management, Global Disaster Resilience Centre, University of Huddersfield, UK**	***Professor Dilanthi Amaratunga:*** *So, for example, can your community handle 2 HILOs at the same time, for example a natural hazard and a Corona virus? ~~And in that sense…~~ Who is available to respond? What medical assistance can be provided if hospitals are treating Covid 19 patients and if there is going to be another major natural hazard? And also, where do we shelter ~~and and and house~~ and where do we evacuate people to, given the need to keep large number of evacuees socially distant from one another if there is a kind of a ~~Covid~~ Covid situation. So, these are actually some of the very complex problems that we will have to deal with.*
00:15	Slide from Professor Dilanthi Amaratunga's powerpoint	***Narration***: Considering these challenges, it is important to develop integrated systems for disaster preparedness which consider the possibility of multiple hazards, systematic risks and cascading impacts on a society.

Transition Animation		
00:25	"Recovery" slide from Prof. Kulatunga's powerpoint (01:10:00) Day 2 / TIIKM J Hilton Day 2 3	***Narration***: The Recovery stage of the Disaster Risk Reduction process is also an important stage where resilience to HILO disasters can be developed. The conference discussed several factors that impact on the recovery process including coordination issues between various stakeholders, financial and other resource allocation constraints and issues related to public trust and cultural sensitivity.
00:25	Visuals of people walking, in offices or in the market place	***Narration***: Considering these, understanding the impact that disasters have on the economy and economic development is critical. Interestingly, at the national and macroeconomic level, the impact that a disaster has on a country's economy was found to be limited. In most situations, while the GDP fell in the year of the disaster, in a relatively short time the GDP levels returned to trend.
00:40	Visuals of poor habitats	***Narration***: However, the situation is significantly different when you consider the impact disasters have on vulnerable communities such as the poor. Here, the evidence strongly suggests that disasters affect the poor disproportionately. Several factors were identified as reasons for this. The poor, for example, tend to live in areas which are more exposed and vulnerable to natural disasters. The assets that they own, such as houses, are of low quality and can be damaged or destroyed more easily. The poor also work in the informal sector of the economy where work is irregular and HILO events tend to impact the economic activity in this sector particularly hard.
00:10	Same as above	***Narration***: Unlike at the national level, the economic impact of HILO events on the poor also tends to be long term and sometimes can have inter-generational effects as well
01:00 (1:08:55 – 1:10:06) Day 1/TIIKM	Visual of Prof. Sonali Deraniyagala speaking Name & Title band **"Professor Sonali Deraniyagala"**	***Prof. Sonali Deraniyagala:*** *Economists have analyzed this using a very very simple conceptual model called the model of the "poverty trap". ~~And the idea here is again very simple…~~ and the idea is that each household needs a minimum asset threshold with which … they use these assets in order to generate wealth or to generate income. And these assets enable them to stay out of poverty. Now these assets could be some land, farmers need land… that could be their asset. It*

	Department of Economics, School of Oriental and African Studies (SOAS), University of London	*could be a small workshop if you are repairing a bicycle. Or it could be skills and education… (break in audio)* *… And if you have an asset above this minimum threshold you could stay out of poverty. If you don't you might fall into poverty and ~~this…~~ you can't rebuild. You are too poor then to buy more land. You are too poor to get another workshop. You are too poor to send your children to school and accumulate, what economists call, human capital as in education.*
00:10	Visuals of poor habitats	***Narration***: HILO events can lead to a loss of these assets and poor households find it very difficult to recover them. This can cause them to remain in poverty for a long time.
00:50 (01:10:52-01:11:55) Day 1/TIIKM	Visual of Prof. Sonali Deraniyagala speaking Name & Title band **"Professor Sonali Deraniyagala"** **Department of Economics, School of Oriental and African Studies (SOAS), University of London**	***Prof. Sonali Deraniyagala:*** ~~Another type of…~~ Another type of asset loss is that once these disasters happen ~~and I 've told you that food prices… so consumption prices tend to go up. And low-income households spend, as we know the majority of their income about 60% in some cases and 40% on food. So,~~ food prices go up and suddenly you have no room to maneuver. You have to spend all your income on food. ~~Or you have to maintain consumption~~. Now, because you have to maintain consumption, what happens is, you might sell your asset. So in order to eat, you might sell your land. In order to eat, you might sell the tuk tuk you have that you are going to use to generate an income. So when you sell this asset, once you sold the asset, the theory is that you can't regain it. Because you are below this asset threshold and you just then spending all your income to eat and do very basic things. So this model has been used by economists to show that HILO events push people into a poverty trap and they tend to remain there in the long term.
01:00		***Narration*** Conference participants discussed all these issues at the final session of the conference and arrived at some tentative recommendations specifically for tackling HILO disasters (as opposed to more frequent ones). Many felt that governments would not make large (or physical infrastructure) investments against such disasters especially in poor countries, since they occur so infrequently, and also since measures against more frequent disasters (albeit of lower consequence) tend to consume their limited budgets. As such, it was considered

		imperative at least to ensure the implementation of non-structural initiatives against HILO disasters. One such initiative would be the conducting of regular drills, such as the IOWave exercise to prepare for another Indian Ocean tsunami, inclusive of actually evacuating coastal dwellers to designated safer ground. Another would be to ensure cross-generational memory of these events by referring to them in science, environment and civics textbooks; and also through vivid descriptions of them in stories to be included in primary or secondary school readers. Where infrastructure investments are made, they should be as cost-effective and synergistic as possible, for example by offering robustness against many hazards simultaneously.
00:25	Visuals of people working together + environment visuals	***Narration***: HILO events present many challenges to human society. However, with greater awareness and greater collaboration researchers, policy makers, societal actors and citizens of this planet are coming together to address these challenges. Together, it is possible to manage, reduce and respond to the risks associated with HILO events and build a resilient society on a healthy planet.
00:05	Fade to Black Closing Screen with Logos	