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INVESTING IN DISASTER PREPAREDNESS AND EFFECTIVE RECOVERY IN SCHOOL PHYSICAL INFRASTRUCTURES

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Abstract

The importance of functioning education infrastructure for the post-disaster recovery of communities is becoming well-acknowledged. Yet, recent natural-hazard events worldwide have highlighted that school communities still face many post-disaster recovery-impeding challenges. A significant investment in resilience enhancement through appropriate disaster preparedness and post-disaster recovery management is needed to tackle such global challenges. This paper summarises a series of stakeholder engagements (through interviews and focus group discussions) aimed at providing evidence-based recommendations to foster a more rapid post-disaster recovery of school physical infrastructures in disaster-prone marginalised communities. The case-study community is in Central Sulawesi, Indonesia – a region still recovering from the 2018 Central Sulawesi earthquake, tsunami, and liquefaction which caused damage to over 1200 schools. The considered stakeholders have significant experience in post-disaster recovery management in Central Sulawesi. This paper identifies early-response funding mechanisms, true collaborations between stakeholders, and improved capacity for self-organisation as critical elements for an inclusive, sustainable, safer, and more resilient school physical infrastructures. Although the discussion in this paper focuses on Central Sulawesi, the project's outcomes are scalable to other regions in Indonesia, South-East Asia, and other disaster-prone developing nations.

Keywords: - resilient recovery, school physical infrastructure, preparedness, disaster risk reduction, stakeholder engagement

1 Introduction

Natural hazards (e.g., earthquakes and their cascading hazards, floods, fires, landslides, and hurricanes) can strike communities with little or no warning. Due to the substantial economic and life losses they can generate, the impact of these events on critical infrastructure systems is always of enormous concern. Typically, one of the most affected critical infrastructure systems is schools. Table 1 provides an overview of global disaster impacts on school infrastructure in the last two decades. As emphasised by the table, the global school infrastructure has been constantly at the mercy of these disasters.

The Sendai Framework for Disaster Risk Reduction [1] emphasises the need for communities to understand their disaster risks, strengthen their capacity for disaster risk management and reduction through effective policies, invest in disaster risk reduction for resilience, enhance disaster preparedness for effective response, and ensure the "Build Back Better" concept is upheld in recovery, rehabilitation and reconstruction. The *Comprehensive School Safety Framework* and the *Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector* [2] highlight the need to foster a resilient recovery in education systems. Indeed, education continuity should be one of the primary goals of any post-disaster recovery program. The need to ensure school children return to school within the shortest time is reinforced by evidence of the susceptibility of out-of-school children to exploitation and violence [3] and its implications on their psychological well-being and long-term development. Despite the high social vulnerability of school children, school facilities are typically not prioritised within the immediate response phase. Hence, it is essential to ensure improved school infrastructure resilience in hazard-prone countries is achieved in advance of a future disaster.

Table 1 - Distribution of major natural hazard-induced school damages in the last two decades [4–6]

Year	Country	Disaster	Number of damaged schools
2004	Indonesia	Tsunami	2066
2008	China	Earthquake	10000
2009	Indonesia	Earthquake	2800

2010	Haiti	Earthquake	4000
2010	Pakistan	Flood	11000
2015	Nepal	Earthquake	5000
2013	Philippines	Typhoon	2500
2018	Indonesia	Earthquake + Tsunami	2700

Several studies [7–10]) have investigated the post-disaster recovery of school physical infrastructures. A detailed critical review of these studies is outside the scope of this paper. However, most of these studies underline that the post-disaster recovery process is plagued by various socio-cultural, political, technical, and environmental factors that influence the capacity for communities to recover fast and build back better simultaneously. For example, Ghafory-Ashtiany and Hossein [9] assessed the (re)construction projects in Iran following the 2003 Bam earthquake and highlighted the good quality of school (re)construction projects. It is noted that most of the school buildings were still under construction over three years after the earthquake, and the authors concluded that post-Bam reconstruction projects were delayed mainly because of the government's lack of recovery management plans. Westoby et al. [10] conducted interviews with 20 stakeholders in Nepal's post-2015 Gorkha earthquake recovery projects. The authors highlighted transportation of construction materials and accessibility as the critical challenge of (re)construction projects in earthquake-affected areas. Gathering information on the post-disaster recovery of school infrastructure from global events provides an opportunity for the global disaster risk reduction and resilience enhancement community to access data for evidence-based research studies and practical decision-making for improving future disaster resilience.

This paper aims to provide evidence-based recommendations to foster a resilient post-disaster recovery of school physical infrastructures in disaster-prone marginalised communities. To achieve the aims of this paper, the authors carried out sidewalk and remote rapid screening of 2536 school buildings in Central Sulawesi and interviewed over 40 stakeholders (including government and non-governmental organisation (NGO) officials, engineers, contractors, university academics, and school principals) actively involved in the post-2018 recovery process. The rapid screening of the building inventory and interviews with the stakeholders provided information used in creating a series of questions for focus group discussion with the stakeholders. The questions aimed at understanding the success and challenges faced by the stakeholders during the recovery process. Furthermore, the stakeholders had the opportunity to brainstorm solutions to the challenges together. Also, the stakeholder engagement was useful in developing an analytical post-disaster recovery modelling framework for education systems. This analytical post-disaster recovery modelling framework is presented in a separate study [11].

This study is part of a larger international interdisciplinary project (referred to as the "Resilient School Hubs project") by the current authors aimed at fostering resilient recovery in displaced communities of the Central Sulawesi region of Indonesia via school-based hubs. The project team is made up of structural engineering, psychology, and water, sanitation and hygiene researchers from the University College London (United Kingdom), Universitas Syiah Kuala (Indonesia), and Tadulako University (Indonesia).

It is noteworthy that although the discussion in this paper focuses on Central Sulawesi, the authors believe that the project's findings and outputs are scalable to other regions in Indonesia, South-East Asia, and other disaster-prone developing nations.

2 Role of schools in community resilience

Achieving a desirable level of community resilience requires extensive work and resources in every disaster cycle phase – mitigation, preparedness, response, and recovery [12]. Schools are one of the critical infrastructure systems that can play an enormous role in disaster preparedness, response, and recovery. Aside from guaranteeing the life safety of teachers and pupils in the schools, school facilities can serve as relief centres, storage, supply, and communication hubs. They can also serve as a bonding hub for members of the communities. In a pre-disaster scenario, schools can serve as a site of disaster preparedness learning activities for school children and the community as a whole and training hubs for disaster responders.

Community resilience is enhanced if schools can fulfil these functions. However, for this to happen, it is essential for schools to also have good disaster preparedness and recovery management measures in place. Disaster risk reduction and pre-disaster planning have long been more cost-effective than post-disaster response and recovery [13]. Hence, a community needs to understand the vulnerabilities of their school infrastructure, find ways to mitigate disaster impacts on schools, and also identify ways in which schools can effectively serve the community in pre- and post-disaster scenarios without compromising education continuity.

Post-disaster school recovery is complex and cannot be quantified using one single metric. School recovery can be treated in both physical and non-physical domains. The physical domain is associated with the post-disaster recovery of infrastructure required for education continuity (e.g., classrooms, laboratories, toilets, electric power, and water utilities). The physical domain recognises that the quality of education services can be related to the general state of available infrastructure at any given time. The non-physical domain is associated, for instance, with the post-disaster management structure and psychosocial recovery of school children and staff. The non-physical domain recognises the importance of children's well-being to achieving the schools' intended aims and ensuring successful academic performance.

While the authors recognise the importance of recovery in the non-physical domain, it is highlighted that the current study focuses on the post-disaster recovery of the physical school infrastructure. Research studies (e.g., [14–16]) provide information on the impact of post-disaster child trauma on school recovery. Future studies will look at aggregating the physical and non-physical domains of recovery in quantifying post-disaster resilience of schools.

3 Central Sulawesi region

Sulawesi island is a tectonically-active region located at the junction of the Australian, Sunda, and Philippine plates [17–20]. Two major faults, the Palu-Koro and the Matano faults, are situated around the island. The Palu-Koro Fault is an active north-northwest fault, influenced by the interaction of major subduction zones, which has triggered various geological natural-hazard-induced disasters [21]. The geological and hydrological configuration of the Central Sulawesi region makes it susceptible to ground shaking-induced tsunamis. Historically, this region has been subjected to over ten earthquake-induced tsunamis in the last two centuries [22]. In Palu bay, Central Sulawesi province, the moment magnitude (M_w) 6.2 earthquake occurred on December 1, 1927, triggered tsunami waves up to 15 meters recorded in Palu. The number of casualties was unknown [23]. After this 1927 tsunami, two other tsunamis related to the Palu-Koro fault were recorded on August 14, 1968, and January 1, 1996 [19]. This study focuses on the aftermath of the most recent catastrophic event to hit the region, i.e., the 2018 Central Sulawesi earthquake and tsunami.

The 2018 Central Sulawesi event significantly damaged residential buildings, lifelines, and school infrastructure. The intense ground shaking in the epicentral area triggered liquefaction, and significant landslides on the island [24]. Moreover, a tsunami was triggered that caused onshore flow depths of up to 5.5 meters around Palu Bay [25]. Together, these hazards lead to over 4,000 fatalities and 165,000 displaced people [26]. At least 1,299 schools were reported as damaged or collapsed, affecting about 184,000 students. Over a year after the event, 67% of the schools were still damaged and unoccupiable, forcing students to attend schools in shifts due to limited temporary shelters [27]. Most of the observed damage has been attributed to poor design practices, the use of poor construction materials, and corrosion-induced reinforcement degradation [28].

Given the region's susceptibility to multiple natural hazards and the significant proportions of marginalised individuals/households within the population, Central Sulawesi became an ideal case study for the project. Furthermore, the ongoing recovery process in the region provides a unique opportunity to interact with key stakeholders across a wide range of sectors involved in post-disaster recovery management and learn from the field.

4 Pathway to stakeholder engagement

Technical guidelines for implementation of safe schools for children in Indonesia (e.g., [29]) highlight the need to (a) reduce education activities disruption while ensuring inclusive health protection for all school children; (b) ensure availability and access to safe learning centres during the emergency and recovery phases; (c) position schools as hub for post-disaster emergency and recovery coordination; and (d) position schools are hubs to tackle poverty, health and illiteracy-related issues. As highlighted by the wide-spread damage to school infrastructure and subsequent disruption to education following the 2018 Central Sulawesi event, the resilience of schools in Central Sulawesi has not attained the level desired by the Indonesian government. One of the ways to assess the successes and challenges of the post-2018 Central Sulawesi recovery process is through stakeholder engagements.

It is unrealistic to assess or improve the resilience of a system or community without first understanding the existing conditions and historical performance of the system or community in disasters. One of the interesting aspects of this study was the significant link between field survey of school infrastructure, analytical modelling, and stakeholder engagement through interviews and workshops to investigate recovery-related issues. Figure 1 presents the links between each aspect of the project.

According to the Indonesian Ministry of Education, Culture, Research, and Technology [30], over 3700 elementary and junior high schools serve school children in Palu, Sigi, and Donggala. Details on the performance of the school buildings following the 2018 Central Sulawesi earthquake are reported in various studies (e.g., [28]) and other government sources.

As shown in Figure 1, firstly, the authors carried out a review of available information on the damage state of schools in the Central Sulawesi region. This review entailed examining photos of the post-disaster state of the structural and non-structural systems of schools available in a government-sourced database. This review provided information on the required recovery process (i.e., repair, retrofit, replace, relocate) for the damaged buildings. Furthermore, the review served as a starting point for developing a school building inventory for the purpose of this project. From the reviewed schools, a total of 30 schools with 206 buildings were selected for detailed assessment. The detailed assessment entailed a sidewalk survey of all school buildings and interviews with each principal in the 30 schools. The location of the schools is shown in Figure 2. Information on the hazard history and proximity to hazard sources, proprietorship (state- or private-owned), damage states of schools after the 2018 event, and intervention type in schools (i.e., repair, retrofit, reconstruction, relocation) were considered in selecting the 30 schools.

From an engineering perspective, it was of interest to develop a large building inventory that is useful for vulnerability assessment and community-level recovery modelling work. The typical approach for building inventory development is a rapid sidewalk screening of each building in the region. Rapid sidewalk screening is a quick way of assessing the building vulnerability based on visual inspection of its structural and non-structural systems [31]. However, time and resource (human and budget) constraints make it practically impossible to conduct a rapid sidewalk visual screening of all the buildings in a region of interest. Therefore, a remote screening of 424 other schools was carried out. In addition, to the 30 schools that were visited, a total of 454 schools were screened - corresponding to about 15% of schools in Palu, Sigi, and Donggala.

The 424 schools were drafted from the list of schools in Palu, Sigi, and Donggala which is publicly available on the Indonesian Ministry of Education, Culture, Research, and Technology website [30]. Information on school proprietorship type (i.e., private or state), the population of staff and students, school level (i.e., primary, junior, or senior high school) of each school is also provided on the website.

Prior to deploying the remote screening technique to these 424 schools, the initial 30 schools (where the sidewalk screening was carried out) were also screened remotely. An inter-rater reliability analysis of the data collected from both the sidewalk and remote screenings of the 30 schools was then used to prove the reliability and deployability of the remote screening method to the remaining building portfolio. Hence, a further 424 schools were screened remotely, totalling 454 schools – this corresponds to a total of 2536 school buildings ((i.e., schools may include multiple buildings). More information on this is available in [32]. A database of the screened schools (which contains details population of school children, structural and non-structural information of each school building, and potential structural vulnerabilities) has been collated by the authors to provide a testbed for researchers seeking to carry out disaster risk management-related studies. A rapid visual survey (RVS) form, developed for the purpose of this study, was used to collect information on the location, occupancy information, structural and non-structural attributes, and vulnerabilities of each building. The RVS form and collated database are available in [33]. By combining the output of the remote survey and the sidewalk survey, the following findings were obtained: (a) the majority of school buildings in Central Sulawesi are one-story and are typically confined masonry buildings; (b) although few, typical two-story structures are made of reinforced concrete frames with masonry infills; (c) majority of the buildings were built before the implementation of the 2012 seismic codes; (c) the majority of the two-story structures are either L- or C-shaped, making them potentially susceptible to torsional irregularities.

The recovery process of these schools was tracked through a series of structured and semi-structured interviews with stakeholders involved in the recovery process – namely, school principals, university academics, NGO workers, government officials, contractors, and engineers (See Table 2). Structured interviews were targeted at school principals as one of the aims of the interviews was the collection of quantitative data for statistical investigations (See Section 5). Semi-structured interviews were targeted at NGO workers, government officials, contractors, and engineers in order to collect qualitative and open-ended data and explore the thoughts, beliefs and experience of the stakeholders (See Section 6). All guiding questions are publicly available. The location of the guiding questions for each stakeholder engagement is presented in Table 2.

The gathered data provided information on the recovery of the power systems, water systems and school buildings. The stakeholder interviews provided information on recovery challenges.

Although such information is not entirely novel, as similar challenges have been observed in past events, a research gap identified in this project was the lack of methodologies to incorporate these challenges in analytical recovery modelling frameworks. A key step towards inclusive recovery is understanding the likely effects of various policies and challenges on the recovery trajectory of a disaster-hit community. Hence, a probabilistic framework for modelling the post-disaster recovery of education and utility systems was developed and is presented in [11]. The proposed framework has key features such as (a) considering socio-cultural, economic, political, technical, and environmental factors that influence post-disaster recovery trajectory; (b) proposing a methodology for reconstruction prioritisation; (c) including a methodology for predicting robustness and recovery times of power and water systems.

Finally, using all the information gathered from the stakeholders' interviews and analytical modelling, a series of guiding questions were developed for a final stakeholder engagement – a workshop aimed at leveraging the expertise of the stakeholders in recommending resilience-enhancing solutions for schools. The subsequent sections in this paper discuss the stakeholder interviews and workshops conducted through the study. Ethics approval was obtained for these stakeholder engagement exercises from UCL's Research Ethics Committee. Furthermore, in-country clearance was obtained through Syiah Kuala University and Tadulako University in Indonesia.

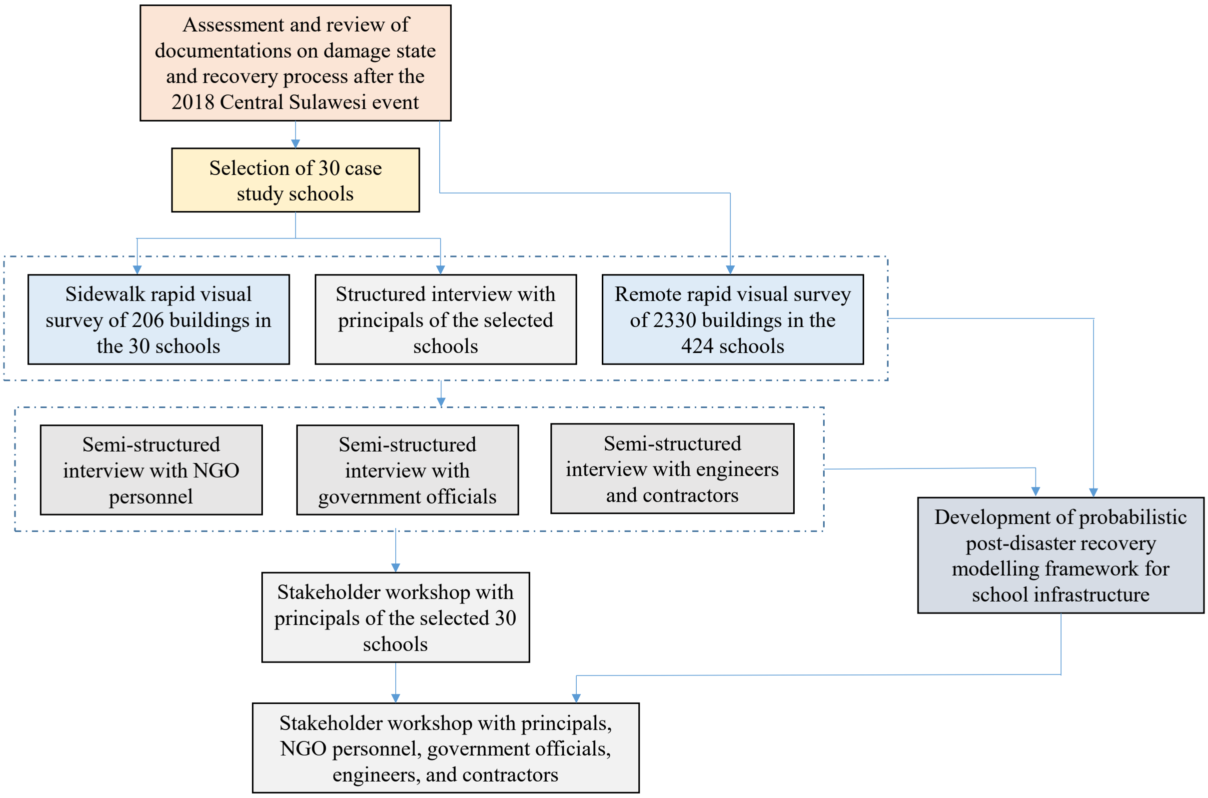


Figure 1 – Links between stakeholder engagements and analytical studies

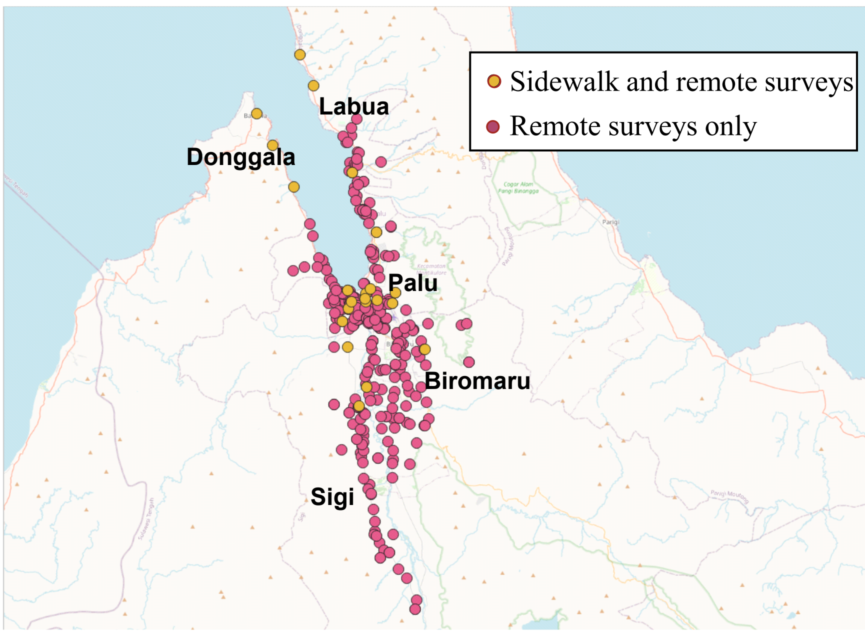


Figure 2 – Distribution of schools considered in the study

Table 2 – Adopted methods, questions, and respondents

s/no	Area of inquiry	Adopted method(s)	Guiding questions	Remarks/Stakeholders
1	Pre-2018 disaster preparedness level and post-2018 earthquake disruption to education continuity and recovery trajectory of schools	Semi-structured interview	See Opabola et al. (2022b)	Participants: 30 school principals
2	Successes and challenges of the school recovery projects	Semi-structured interview	See Appendix A.1.1	Participants: Six NGO officials Two government officials Four civil engineers, and two building contractors
3	Identifying solutions to the preparedness challenges in the Central Sulawesi region	Focus group discussions	See Appendix A.1.2	Participants: 30 school principals
4	Identifying solutions to the recovery challenges in the Central Sulawesi region	Focus group discussions	See Appendix A.1.3	Participants: 36 participants four NGO officials, four government officials, eight civil engineers and building contractors, five school principals, and 15 university academics

5 Principal interviews in 30 schools

Disaster preparedness is one of the most critical components of disaster risk reduction. School administrators and teaching and non-teaching staff should be prepared for emergencies and disaster-inducing natural hazards. Disaster preparedness of schools typically entails the following actions: (a) identifying all potential hazards the school is susceptible to; (b) constituting a school emergency and disaster preparedness committee; (c) designing, developing, and implementing an emergency and disaster preparedness plan; (d) procuring and maintaining all necessary survival kits; (e) conducting regular emergency drills. Detailed guidance on these actions is readily available in published literature such as [34] and is not reproduced here.

With the knowledge that the majority of the schools in Central Sulawesi had prior training on disaster preparedness, aside from studying the recovery process in schools, it was also of interest to understand the disaster preparedness culture in place before the 2018 Central Sulawesi event. Therefore, a series of questions were prepared for a semi-structured interview with 30 principals in the region. The questions were designed to gather information on the hazard history, preparedness level, damage state of school buildings following the 2018 event, intervention type and time for each school building, and recovery time to power and water systems in the school. The interview questions and raw data output are publicly available in [33].

Figure 3a shows the distribution of the number of years the interviewed principals had spent working in the schools. Since the interviews were conducted almost three years after the 2018 event, respondent reliability was rated high if they had spent over three years at the school. 26 of the 30 principals provided information on their working period in the schools. Of these 26, only one principal was at the school for a period fewer than three years. Hence, the principal interview output was rated to have high reliability.

As mentioned earlier, post-disaster education continuity is the primary indicator of the resilience level of any education system. According to the principals, all 30 schools were closed following the 2018 event. The principals were asked to provide information on the closure duration of their schools. Figure 3b presents the distribution of the school closure duration for the 30 schools. As shown in the figure, over half of the schools were closed for more than 30 days. Only two schools were opened within a week following the 2018 event. The slow pace of education continuity can be attributed to the fact that over 80% of the school principals noted that at least one building in their school premises was damaged following the event (Figure 3c).

It was of interest to understand the link between the resilience level of the education system in the community and the disaster preparedness level in place prior to the disaster. Figure 4 provides a graphical representation of the collated information on preparedness. As shown in Figure 4b, despite all the schools experiencing at least one hazard within the last 10 years (Figure 4a), only 20% of the schools conduct frequent emergency drills (defined as minimum of one drill per school term). The majority of the schools do have evacuation maps but most schools do not have survival kits. The lack of survival kits was of concern as it means that the majority of the schools do not have the capacity to provide first-aid assistance to student casualties in the event. Figure 4 suggests that the resilience level of the schools could have been impacted by the poor preparedness level. This information formed the basis of a workshop described later in this paper.

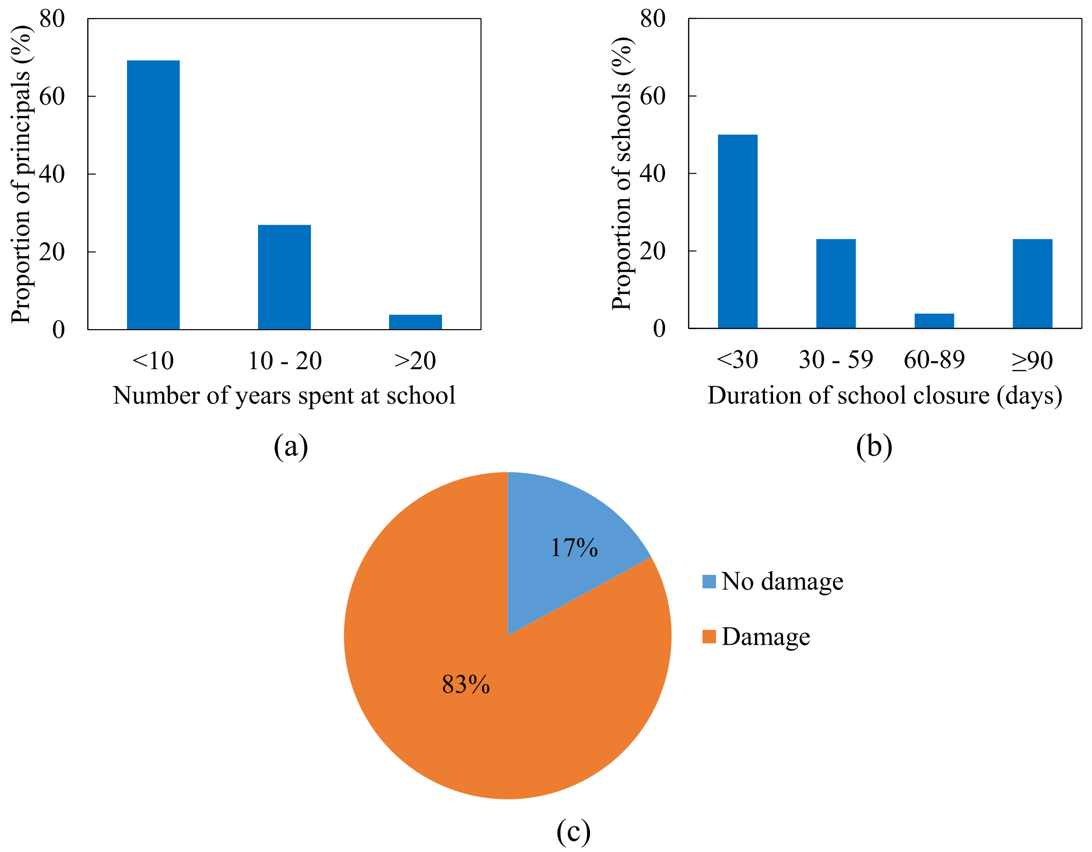
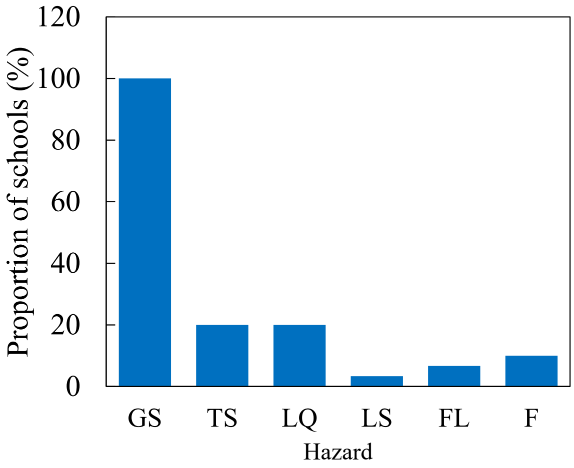
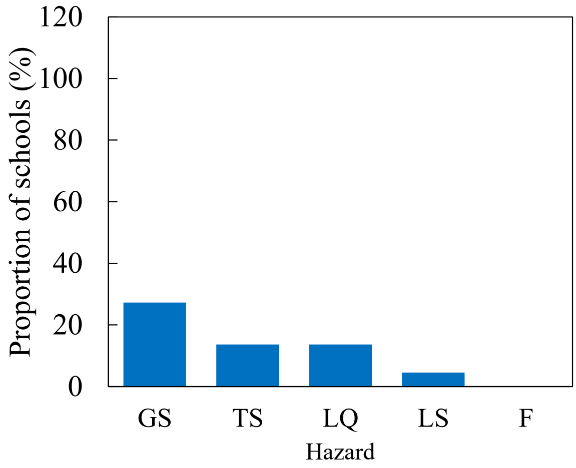


Figure 3 – (a) Distribution of the number of years spent by principals at the schools (b) Distribution of school closure duration following the 2018 earthquake and tsunami (c) Presence of damage to school buildings

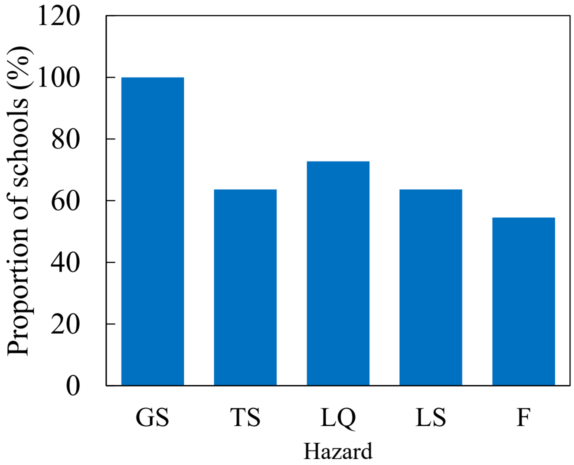
The principal interviews also provided information on the functional state and recovery time of the schools. The overall functionality of each school was quantified based on the damage state of the school buildings and operability of the utility systems (i.e., water and power) in the schools. Four functionality states were considered based on the structural safety of the building, occupiability, and operational state of the utility systems – safe and occupiable building with 100% functionality of necessary utility systems (FL0), safe and occupiable building with reduced functionality of necessary utility systems (FL1), safe but unoccupiable building (FL2), and unsafe building (FL3). Figure 5a provides a cumulative distribution function (CDF) of the collated information on the recovery time for buildings in different functionality levels. The figure shows that the post-disaster functionality state significantly influences the recovery time. The CDF of the restoration time for the power network is presented in Figure 5b. The median restoration time for power supply in the schools was about 20 days.



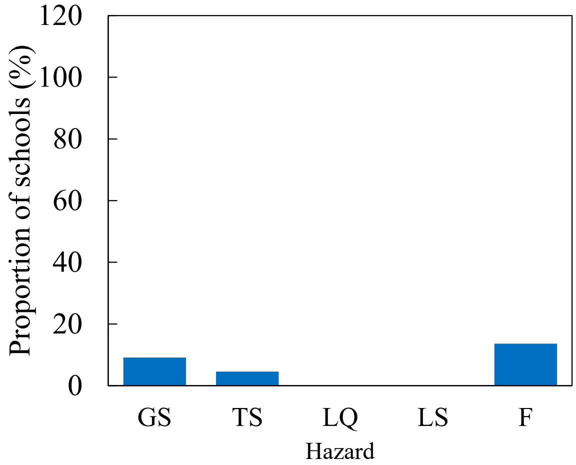
(a) Hazard history in the last 10 years



(b) Schools conducting frequent drills



(c) Schools with evacuation maps



(d) Schools with survival kits

Figure 4 – Key information on the hazard history and preparedness actions in schools (GS – ground shaking, TS – tsunami, LQ – liquefaction, LS – landslides, FL – flood, F – fire)

The school principals were asked to provide recommendations to deal with disaster-induced power loss. The majority of the principals identified the installation of solar panels in the schools as the ideal sustainable approach to avoid power disruption. A few principals also suggested the installation of fuel-powered generators as a way to add power supply redundancy.

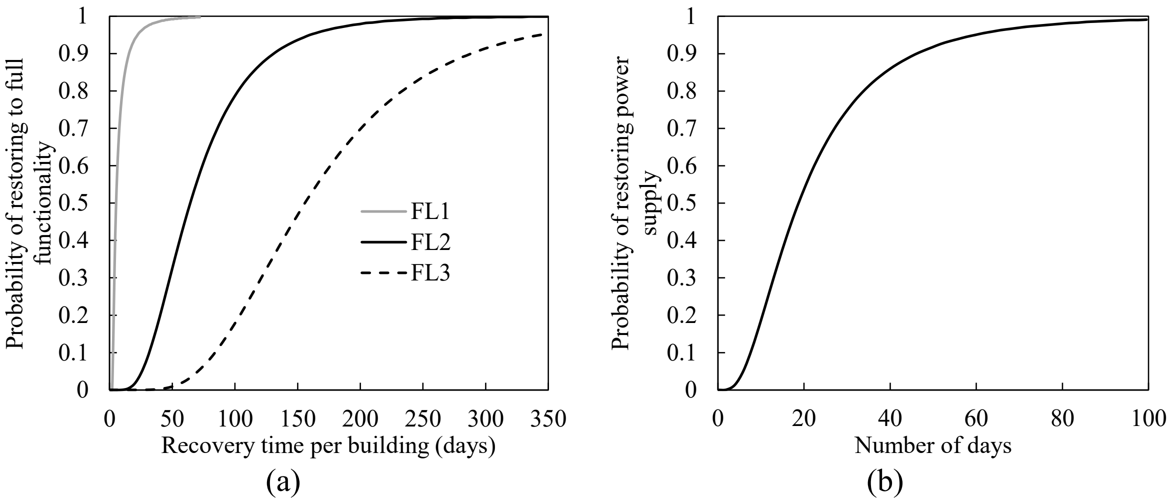


Figure 5 – Cumulative distribution function of reported (a) recovery time for school buildings; (b) recovery time for power supply (NB:- FL1 refers to safe and occupiable building with reduced functionality of necessary utility systems, FL2 refers safe but unoccupiable building and FL3 refers to unsafe building)

6 Stakeholder interview

To understand and identify the successes and challenges of the school recovery projects in Central Sulawesi, a series of interviews were conducted with stakeholders involved in the recovery process. The stakeholders included two government and six NGO officials, four engineers, and two contractors. The list of stakeholders was developed from publicly available records and recommendations from the school principals.

The NGO official interviews helped track the response and recovery activities of the NGOs. These interviews were semi-structured, and the questions aimed at understanding (a) the timeline of response and recovery activities; (b) the approach used in choosing the type and number of schools; (c) the challenges and success of the tender process; (d) which steps in the recovery process caused significant delay; and (e) the financial aspect of the recovery.

Three of the interviewed NGO officials had projects mainly on the rehabilitation of water, sanitation and hygiene (WASH) facilities, while the other three NGOs were majorly involved in school building reconstruction and rehabilitation projects. Regarding the mobilisation time for the WASH facilities, two NGO officials noted that the post-disaster condition assessment of WASH facilities was carried out four months after the 2018 event. This delay was attributed to the community's focus on other sectors. The inspection of WASH facilities was noted to have taken about one month, followed by another two weeks to make decisions on the appropriate intervention strategy. In terms of criteria for making decisions on the appropriate intervention strategy, the NGO officials noted that they relied on recommendations from the department of education, budget availability, and data from the condition assessment survey. According to an NGO official, schools were prioritised for WASH facilities reconstruction if (a) there is an existing water source on the school premises (because there was no budget for constructing new wells or other water sources), (b) availability of a suitable land area for building WASH facilities (because the toilet designs were fixed and could not be modified for any school), and (c) the school population exceeds 64 students (each WASH facility design has four toilets, assumed to serve 16 pupils each). In the case where the number of students was below 64, the schools were put on a separate list for the construction of a WASH facility with two toilets. The average construction time for each WASH facility (i.e., with four toilets) was four months.

Regarding school building reconstruction projects, all the NGO officials mentioned that they selected their reconstruction list from the school damage assessment data provided by the government. An NGO official noted that an independent damage assessment was also carried out by the NGO. The project management process for all NGOs involved in the reconstruction process were similar. For consistency and clarity sake, the subsequent discussions will focus on answers provided by an NGO (hereafter referred to as NGO X) that handled one of the biggest reconstruction projects (in over 20 schools) in the region.

According to the interviewed official of NGO X, schools were selected for reconstruction projects if (a) the affected school buildings are government-owned and were heavily damaged, (b) the school had not been selected for intervention by another NGO, (c) the school is not located in the government-designated red zone, (d) the local authorities have provided a clear land free from debris, (e) the local authorities agrees to be responsible for building permits procurement and other government-related logistics, and (f) the local authorities agree to take over and maintain the newly-built structures. Furthermore, one of the NGO's policies was to only replace damaged buildings, i.e., all reconstructed buildings must have the same number of stories and classrooms as the damaged buildings.

The timeline of NGO X intervention project is presented in Figure 6. As shown in the figure, NGO X project agreement was signed about three months after the 2018 event. Following the aforementioned criteria, the final reconstruction list for NGO X was developed about eight months after the 2018 event. The tender process for building designs was completed 14 months after the disaster (as noted by the official, two tender processes were needed because the first one was unsuccessful), and the design contract was only awarded 18 months after the disaster. The tender process for the building contractors was completed about 29 months after the disaster, with the contract awarded about 33months after the disaster. Hence, the construction projects only began almost three years after the event. As at July 2022, the construction projects are still ongoing. All affected schools are still using temporary learning centres. The project delays have been attributed to the prolonged tender process, COVID-19 lockdowns, and lack of skilled contractors.

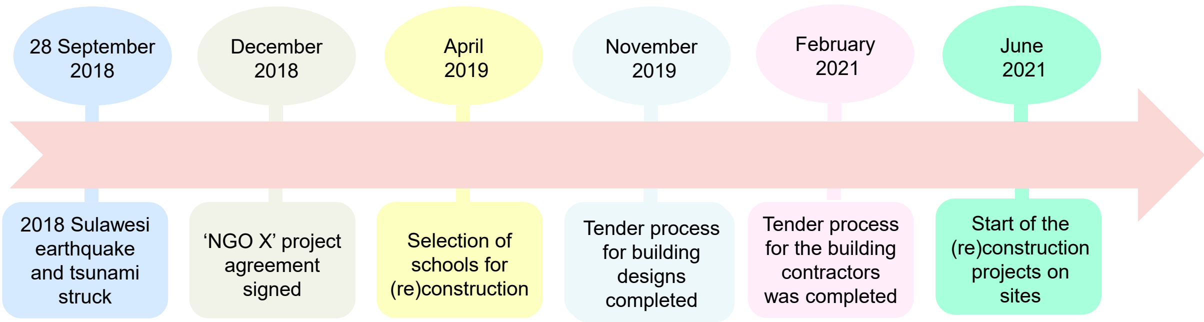


Figure 6 – Timeline of NGO X intervention project

All interviewed NGO officials (WASH and school building projects) highlighted poor material availability, lack of experienced manpower, prolonged tender process, and delays in building permit procurement as the main recovery-impeding factors. The lack of experienced manpower was attributed to the high demand for skilled labour across infrastructure (i.e., residential buildings, port facilities, administrative buildings, utility networks, and so on). One of the respondents noted that the government agency in charge of awarding building permits was handling multiple projects simultaneously. Hence, the turnover time was slow.

The interviews with the government officials, engineers, and contractors aimed to gather information on recovery delays and their perspectives on the success and challenges of implementing build-back better strategies. These interviews further provided details on technical, socio-political, cultural, and environmental challenges trailing both community-managed and NGO-managed school reconstruction projects. An example is a case of a school located in the designated tsunami red zone (and serving the local fishermen community), which the government recommended for relocation after the 2018 event. The relocation project has stalled because the school parents are unwilling to accept an increased travel time for their children every day. Furthermore, the fishermen's community prefers to have a school as close to them as possible.

7 Stakeholders workshop

As shown in Figure 1, analyses of the interview data and numerical modelling provided sufficient information to understand the limitations of the school preparedness and the recovery-impeding issues the school community faces. However, ensuring the recommendations are appropriate to the local context is crucial. Hence, another stakeholder engagement activity was conducted. In contrast to the previous stakeholder engagement (i.e., the interviews), a stakeholder workshop was organised. The stakeholder workshop was structured as a focus group discussion, allowing each participant to provide their perspectives on each question. The focus group discussion was designed to initially introduce the stakeholders to the outputs of the stakeholder interviews and analytical modelling so as to obtain their validation of the results. Subsequently, a set of guiding high-level questions was posed to the stakeholders. The questions were structured so that each stakeholder could discuss fundamental problems they personally faced, and the entire group could brainstorm solutions. Facilitators ensured interaction between stakeholders through prompts or invitations to express opinions.

Two separate stakeholder workshops were conducted. The first workshop consisted of the 30 school principals previously visited during the survey phase. The workshop took place in person in one of the schools in Palu. Given that the principal interview's primary outcome was the schools' inadequate preparedness level, the first workshop (an in-person workshop) with the principals focused on discussing issues and solutions associated with the insufficient preparedness level. Table 3 provides an overview of the key problems and solutions highlighted by the principals during the workshop. The issues raised centred around the time and financial constraints of carrying out emergency management exercises. The principals collectively agreed that there is a need to infuse modules on disaster preparedness into the curriculum efficiently. It is noted that other recent research studies (e.g., [35]) have discussed pathways to disaster risk reduction education integration in Indonesian schools. Also, they recommended that schools need to improve their capacity to conduct emergency management exercises by committing some of their funds. Following the focus group discussion, we (the researchers) conducted a training session on school emergency management plan and survival kit preparation and implementation.

The second workshop targeted key government officials, NGO officials, engineers, and contractors actively involved in the post-2018 Sulawesi school recovery projects. Furthermore, the school principals (from the first workshop) were also invited to participate in the workshop. The school principals were invited because it is believed that the perspective of the communities on the recovery projects can be highlighted by the school principals, especially because some of the engineers and contractors working in Central Sulawesi are not from the region. Since the stakeholders are spread across Indonesia, this workshop was conducted online. A total of 36 stakeholders were in attendance.

As mentioned earlier, the second workshop also kickstarted with a series of presentations on the findings from the stakeholder interviews and analytical modelling. The subsequent guiding questions focused on preparedness, response, and recovery. The general discussions have been grouped into (a) effective recovery and building back better in marginalised communities; (b) understanding the vulnerabilities, risks, and uncertainties associated with disaster risk management; (c) ensuring post-disaster education continuity; and (d) understanding capacity for self-organisation, social connectedness, and empowerment. Table 3 summarises the key discussions and recommendations from the second workshop, classifying them into a number of thematic groups.

In general, all participants agreed that recovery is not "business-as-usual" for the government, NGOs, and the entire community. Hence, it is counterproductive to rely on business-as-usual governance and policies. Also, the influence of socio-cultural factors on recovery cannot be underestimated. There are shreds of evidence of socio-cultural factors superseding technical factors in the recovery process (an example is the previously highlighted school relocation issues in the fishermen's community).

It is noted that some of the discussions could fit into multiple thematic groups. For example, while 'Poor information to school principals' has been grouped under the 'understanding the risk, vulnerability, and uncertainties' category, principals noted that a lack of knowledge on the post-disaster residual capacity of some buildings negatively affected their continued use.

Rapid construction technology (e.g., modular construction) has been advocated to have the advantage of helping communities recover faster. For example, Indonesia's popular modular construction technology, Rumah Instan Sederhana Sehat (RISHA), or healthy, simple, and instant houses project, is targeted toward residential building construction. However, several school reconstruction projects have adapted this technology. Engineers have, however, highlighted design standardisation issues that can influence the vulnerability of these structures when adopted as schools. For example, it is unknown if appropriate design checks are carried out when modifying the structural components' dimensions from the original design template.

Table 3 – Challenges and recommendations for effective preparedness and recovery management in schools

s/no	Problems	Description	Solutions/Recommendations
Effective preparedness (from the first workshop)			
1	Time constraints	The teaching schedules are significantly tight, and the school managements have challenges in sparing time for drills and training workshops.	Local government must insist on frequent drills in schools and schools management must report their drills to a government agency. There is a need to efficiently infuse modules on disaster preparedness into the school curriculum.
2	Financial constraints	The lack of survival kits, updated evacuation plans, and training workshops is attributed to insufficient funds to cover the logistics.	Some principals agree that they cannot rely on the government to update their emergency management plans and kits. They recommend that school principals must dedicate a proportion of their School operational fund to emergency management.
Effective recovery and building back better (from the second workshop)			
3	Delays in bidding and procurement process (planning phase)	The highly bureaucratic and hierarchical system embedded into the bidding and procurement processes results in delays in project starts.	Government and NGOs must realise that post-disaster recovery is not business as usual. Stakeholders need to have a streamlined bureaucratic process during post-disaster recovery.
4	Delays in construction	Significant construction delays due to lack of qualified workforce, inadequate materials, and machinery. In certain cases, some contractors were handling multiple projects simultaneously.	Transfer of skills through training of workforce; appropriate regulations on the maximum number of projects a contractor can manage simultaneously; mechanised construction should be heavily encouraged.
5	Poor quality of construction process	Lack of site inspection process; no quality control checks.	Local universities can aid with quality control tests on materials. Training of supervisory staff. No sanction or punishment was applied to the erratic construction process or the resulting failures post-construction.
6	Problems with scalability	The modular construction technology adopted in Indonesia was originally designed for residential buildings. A number of school reconstruction projects	The government must ensure approved design specifications for modular school buildings to ensure the detailing are code-conforming.

		have, however, adopted this technology without appropriate design checks. Hence, these schools may not exactly conform to the 'build back better' principles	
7	Problems with relocation projects	Land acquisition issues and the unwillingness of schools to relocate from tsunami-prone regions.	Better community awareness on the high social vulnerability index of school children and the physical vulnerabilities of single-story structures to tsunami.
8	Materials transportation to remote areas	Transportation of material to remote areas was a big challenge. Precast panels for modular structures could not be transported to remote areas.	Logistics should be incorporated in recovery planning. There needs to be effective planning before precast construction can occur in remote areas.
9	Legal issues	All rehabilitation and reconstruction process was controlled by the law Presidential Instruction Number 10 of 2018 concerning Acceleration of Post-Earthquake and Tsunami Rehabilitation and Reconstruction in Central Sulawesi Province and Other Affected Areas, which expired in 2020. Hence, the reconstruction process is now based on the instruction of the loaner or funder like World Bank, etc.	Local governments need to be in a position to establish a law that can control the rehabilitation and reconstruction process after the expiration of the Presidential law
10	Dealing with debris	Many debris from demolished buildings couldn't be cleared out as there were no sufficient disposal sites. In some cases, there were no funds to deal with the disposal.	More awareness of the applicability of recycled aggregates and other uses of debris from demolished buildings in reconstruction of roads and buildings.
11	Lack of sufficient temporary learning centres	Schools relied on insufficient temporary tents to enable education continuity. Apart from space congestion, students had to deal with poor ventilation, heat, rain, and winds during school hours. In addition, WASH facilities were also lacking.	Temporary learning centres and WASH facilities should be allocated within the emergency fund (e.g. the so-called 'on call' budget in the National/Provincial/District Disaster Management Agency) in case of a disaster occurs at high-risk areas.
Understanding the risk, vulnerability, and uncertainties			
12	Short-term memories	People care about risk and vulnerability only for a few years after a significant event. Afterward, they care less about risk and preparedness. Also, in some instances, the frequency of disasters means people see the associated damages as usual and	The government must invest in continuous awareness of disaster preparedness and the importance of mitigation. Collaboration between government and academia/experts to update disaster risk mapping and support

		attach a religious sentiment to survival.	socialisation and dissemination of findings to the public.
13	Poor information to school principals	School principals are not aware of the risk and vulnerabilities of their schools. They do not have the support and guidance from experts. In cases where schools attempt DIY repairs/retrofits, they are unsure of the effectiveness of these DIY fixes.	The government needs to take serious action on providing support to communities, especially to school administrators, on how to identify vulnerable structures, retrofit/rehabilitate light to moderate damage caused by the disaster
Post-disaster education continuity management			
14	Funds availability	Schools were not prioritised for immediate response. School operational funds (dana BOS) were useful in ensuring faster reconstruction instead of waiting for government or other stakeholders' help. However, schools without such funds had delayed recovery.	The government needs to help with early response funding mechanisms.
Capacity for self-organisation			
15	Lack of inclusiveness/local content	The local communities feel disappointed that the bidding process favours contractors from other regions of Indonesia who do not have local knowledge. Moreover, these contractors subcontract works to local contractors in a poorly managed process.	There has to be a mechanism to ensure local contractors have the opportunity to contribute to their own communities. Suggestions to overcome this is to suggest local government set the restriction rules to involve local contractors from the very beginning of the construction plan, design, and works.
16	Poor management	There has been an effort to strengthen the capacity of local government in terms of self-reliance and self-organisation in anticipating future disasters, for instance, by training the responsible staff for certain positions in the disaster management agency. However, after several months, the persons were often rotated into another new office position or even moved to another department or ministry. This results in discontinuation and unsustainable competent human resources.	The government should have continuity plans tailored for disaster management agencies to ensure there are no knowledge/experience gaps within the agencies at any time. Also, the government needs to adopt simple post-disaster response frameworks/policies and ensure stakeholders at all levels are well-informed about these policies.
17	Lack of funding	The funding allocation for socialisation and dissemination of disaster risk to the community has always been minimal, and it fails to effectively implement the programs sustainably	To impose budget allocation in Municipality/District government annual budgeting plan for community socialisation and dissemination of disaster risk.

Aside from discussing recovery challenges, it was also essential to understand what the school principals considered the most compelling aspects of the recovery process. The school principals highlighted the effectiveness of being empowered as the key to success. A school principal noted that "*during the emergency response, a trauma healing program introduced at school for school teachers was opened to parents willing to participate. This program improved the connectedness between parents and teachers. We feel empowered with our increasing capacity to deal with our trauma*". Another principal noted that "*during the early recovery phase, school children got the opportunity to experience hands-on exercises, tutorials, and advocation by the external organisations (NGOs, local government, universities, religious community organisation, etc.) on WASH management at school and evacuation*". In general, all the success stories highlight the importance of connectedness, trust, collaboration, and empowerment in post-disaster recovery [36]. However, the long-term effect/sustainability of the success stories need to be seen.

Given that the challenges (and the corresponding solutions) highlighted in Table 3 and the success stories are drawn from key stakeholders in the community, the authors believe the recommendations may help local authorities in the region to upgrade existing disaster risk reduction and resilience enhancement strategies. Furthermore, the suggestions may help guide strategy development in countries with similar socio-economic, cultural and political terrain as Central Sulawesi.

8 Conclusions

Disaster risk management at any government level for education infrastructure is geared towards protecting students and teachers from injuries and deaths, ensuring education continuity following any expected hazard and/or threats, strengthening risk reduction and resilience through education, and safeguarding the public and private sector investments in the education sector. However, achieving these goals on a global scale is complicated as there are no 'one size fits all' strategies that apply to all countries. This is attributed to the fact that each region has peculiar socio-economic, cultural, environmental, and political factors that need to be considered to devise effective risk reduction and resilience-enhancing strategies.

Central Sulawesi in Indonesia is undergoing a large-scale recovery following the 2018 earthquake, tsunami, and liquefaction, affecting over 1200 schools. Given the ongoing process, the region was selected as a case study region for a project aimed at understanding the recovery trajectory of school infrastructure in marginalised communities and also identifying evidence-based approaches to foster a resilient recovery in such communities.

To achieve the project's aims, firstly, a series of sidewalk and remote surveys of over 2500 school buildings in Central Sulawesi was carried out to understand the vulnerabilities of school building inventory in the region. Then, semi-structured interviews with school principals and other stakeholders involved in the recovery process (including government and non-governmental organisation officials, engineers, university academics, and contractors) were carried out. These interviews helped understand the effect of the 2018 event, the preparedness level of schools, the post-event recovery trajectory, and the recovery impeding challenges faced by each stakeholder group. The stakeholder engagement highlighted a poor preparedness level of some schools and several challenges affecting reconstruction projects in the region. Finally, focus group discussions were carried out with the stakeholders to brainstorm practical solutions to the identified preparedness and recovery impending issues. The focus group discussions also allowed the stakeholders to discuss successful recovery strategies since the 2018 event.

The school principals identified time and financial constraints as the key deterring factors to carrying out routine school preparedness drills. The stakeholders highlighted stringent government monitoring of school preparedness exercises as the most feasible to ensure school preparedness is at a desirable level. Various socio-economic, cultural, environmental, technical, and political issues were highlighted as significant barriers to the resilient recovery of the education system in the community. Based on the outcome of the stakeholder engagement, it was concluded that early-response funding mechanisms, true collaborations between stakeholders, and improved capacity for self-organisation are the critical elements for an inclusive, sustainable, safer and more resilient education system.

Given that the challenges and the success stories were drawn from key stakeholders with vast experience in the region, the authors believe the recommendations may help local authorities in the area to upgrade existing disaster risk reduction and resilience enhancement strategies. Furthermore, the recommendations may help guide strategy development in countries with similar socio-economic, cultural and political terrain as Central Sulawesi.

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A.1 Appendix

A.1.1 Guiding questions for semi-structured interviews with NGO officials, government officials, engineers, and contractors

1. Which constraints affected the rehabilitation and reconstruction of damaged school buildings?
2. How were these constraints tackled?
3. What were the technical considerations for deciding on the best intervention strategy for the damaged schools?
4. How did the government policies affect the planning and mobilization phases of your projects?

Part ii – social/economic/cultural/political aspects

1. Name, workplace and job title of respondent
2. Names of schools where the respondent's team worked.
3. What did the project entail? i.e. repair, strengthening or reconstruction of XX number of buildings in SMP X school
4. What financial factors were considered before deciding to repair, strengthen, replace or relocate a building?
5. Did the community play a role in the decision-making to replace, strengthen, replace or relocate? What role
6. In case of relocation, were the communities happy about school relocation?
7. What social/economic/cultural factors were prevalent during post-disaster management/response?
8. What social/economic/cultural factors were considered before deciding to replace a damaged building with a permanent or temporary building?
9. What funding sources are available for post-event intervention?
10. For government/NGO projects, what factors affect tender process for (re)construction/design?
11. What factors affected the tender process for (re)construction/design
12. What is the average cost to build a single-story, two-story and a three-story school building?
13. What is the average cost to repair or strengthen a single-story, two-story and a three-story school building?
14. Cost of temporary buildings?
15. Was there an increased cost in construction materials after the event (due to high demands) and by how much?
16. Was there construction material scarcity?
17. What factors influenced material scarcity?
18. Was there labour scarcity and factors influencing labour scarcity?
19. What part of recovery process took more time than expected?

A.1.2 Guiding questions for focus group discussions with school principals

1. What factors make it difficult to carry out drills?
2. What can be done to address these factors?
3. How do you consider differently-abled pupils in your drills?

4. For your own school, how would you involve students and teachers in disaster preparedness?

A.1.3 Guiding questions for focus group discussions with all stakeholders

Questions on recovery

1. Share your experiences on avoidable recovery delays in your projects/schools
2. How could these delays be avoided in the future?
3. In comparison with pre-disaster scenario, how efficient were the post-disaster construction planning and execution processes (bidding, approvals, procurement, execution)?
4. How can these issues be resolved?

Questions on community perception of risk

1. Does the community understand the vulnerabilities and risk associated with school buildings? If so, do we think the risk is acceptable?
2. What is the societal expectation on the performance objectives of school buildings under strong events?
3. Do we believe the new school buildings are less vulnerable (i.e., more resilient)?
4. Do we make risk-informed decisions for our critical infrastructures ?
5. Discuss solutions

Questions on capacity for self organisation and connectedness

1. Are there effective collaboration, coordination and trust between government agencies, NGOs, private sectors, school administrators, and the communities?
2. What are your views on community participation in the recovery process?
3. What are the challenges restricting self-organisation and better connections in our communities?
4. How can these challenges be resolved?

Questions on education continuity

1. Share your experiences on education continuity challenges
2. If not yet mentioned, discuss school relocation cases and how they have influenced learning
3. Do we have cases where schools were used as shelters? If so, did it affect learning? Discuss
4. How can these all discussed challenges be resolved?

Questions on empowerment

1. Do our schools have the sufficient capacity to reduce the risk and vulnerabilities? Do we have policies that ensure capacity building for school administrations?
2. If no, what are the challenges?
3. How can these challenges be resolved?