Damage Risk Reduction Using Indonesian Wooden Culture

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Abstract

Cultural Heritage can play a crucial role in fostering resilience by reducing vulnerabilities and providing precious assets for an affected region's sustainable social and economic development during its recovery phase by attracting investment, creating employment, or providing renewable natural resources. Disaster Risk Management (DRM) strategies allow a systematic approach to identify, assess, and reduce disaster risks decreasing socioeconomic vulnerability. Extensive consultations with the different institutions involved in preserving and disseminating information often contribute to design mitigation measures that align the understanding of various risks among stakeholders and communities, particularly in risk monitoring and emergency response. This article shows a peculiar and exemplary context as that of Indonesia. We want to show that Indonesian wood, constructed following the vernacular tradition, is a source to reduce the risks in that framework. A brief introduction shows how disaster management in Indonesia's plan is essential to protect the community and its tangible and intangible cultural heritage.

Parole chiave

Disaster Risk Management, risk monitoring, sustainability, earthquake-responsive construction, wood building techniques

> The local communities must intervene as leaders in designing,
> moulding and executing sustainable strategies.
> This entails investing more in human resources,
> especially within local populations.
>
> COM Bruxelles, 2001

Why a pre- and post- disaster recovery plan?

Unfortunately, from many post-disaster examples of the last years, we have learned that failure to plan for recovery often produces a rebuilding process that portends the next disaster. In particular, a lack of coordination is the inevitable limitation of essential strategies among the collective intervention of government, non-profit and private resources, and the community. Typically, post-disaster recovery is a delicate phase in which additional factors (debris removal, theft, misclassification, and other

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a b c d

Fig. 1
Fire Risk in wooden building.
a-b Istana Pagar Ruyung, West Sumatera.
c-d Kampung Adat Nggela, Flores.
(Sources: **a** Alfred, 2005.
b YouTube, <https://youtu.be/tfGss9n8egw>.
c IG Robert_xu76, 2021.
d YouTube, <https://youtu.be/BHk05ZiDkWA>.

catastrophes) can amplify the impact. Normally Disaster Risk Reduction (DRR)[1] involves a pre-disaster as early warning, preparedness, and prevention; a post-disaster focuses on relief efforts, recovery, and reconstruction and focuses on reducing impacts from all natural hazards within the foreseeable period.

In particular, climate change adaptation (CCA) is about risk reduction, responding to impacts, and development of smart agriculture with alternative livelihood opportunities to try a reduction in a long-term perspective. Adopting Disaster Risk Management (DRM)[2] strategies allow a systematic approach to identifying, assessing, and decreasing disaster risks by reducing socio-economic vulnerabilities. This result is achieved by addressing environmental and other hazards that trigger catastrophic events. UNDRR[3] targets developing recommendations relative to nature-based solutions that combineenvironmental management approaches with DRR measures and climate impacts. Developing countries are most vulnerable dealing with natural disasters: combining these solutions with the recovery of vernacular knowledge could provide relevant results. Therefore, development cooperation has become a primary application of disaster risk management. Especially in some countries where the building tradition is also transferred orally, as that Indonesian technical construction tradition, management strategies, and documenting how to repair and restore damaged cultural assets often affected by fire accidents become a priority (Fig. 1).

Planning and coordinating mitigation and adaptation strategies can activate local policies to reduce damage and preserve the cultural identity despite catastrophic events. Thus, improving knowledge about local lifestyles, technologies, and livelihoods for reconstruction as learning from past mistakes can guide us on more targeted interventions and complement the current guidelines. Modern technologies can help prioritize and protect the heritage with limited resources by identifying the right combination of measures. Drones and satellite Imagery Data Sources have become basic instruments to detect and monitor damage and, not least, define risk mapping[4].

Geo-climate

Such is the case that the archipelago of Indonesia with the constant risk of volcanic eruptions, earthquakes, floods, and tsunamis. Its location is in the Pacific Ring of Fire[5], with a high degree of tectonic activity. Over the past twenty years, the country often coped with devastating natural disasters. In peculiar coastal areas, immovable assets are particularly vulnerable to climate change impacts (Pecchioli, 2023a). Heavy rainfall exacerbates the damage and causes localized structural collapse. For example, a 5.6 magnitude earthquake struck the mountainous Cianjur region on the west coast of Indonesia's Java Island just before 1:30 p.m. on November 21, 2022. The quake's epicenter was relatively shallow at about 6.2 miles in depth (Fig. 2).

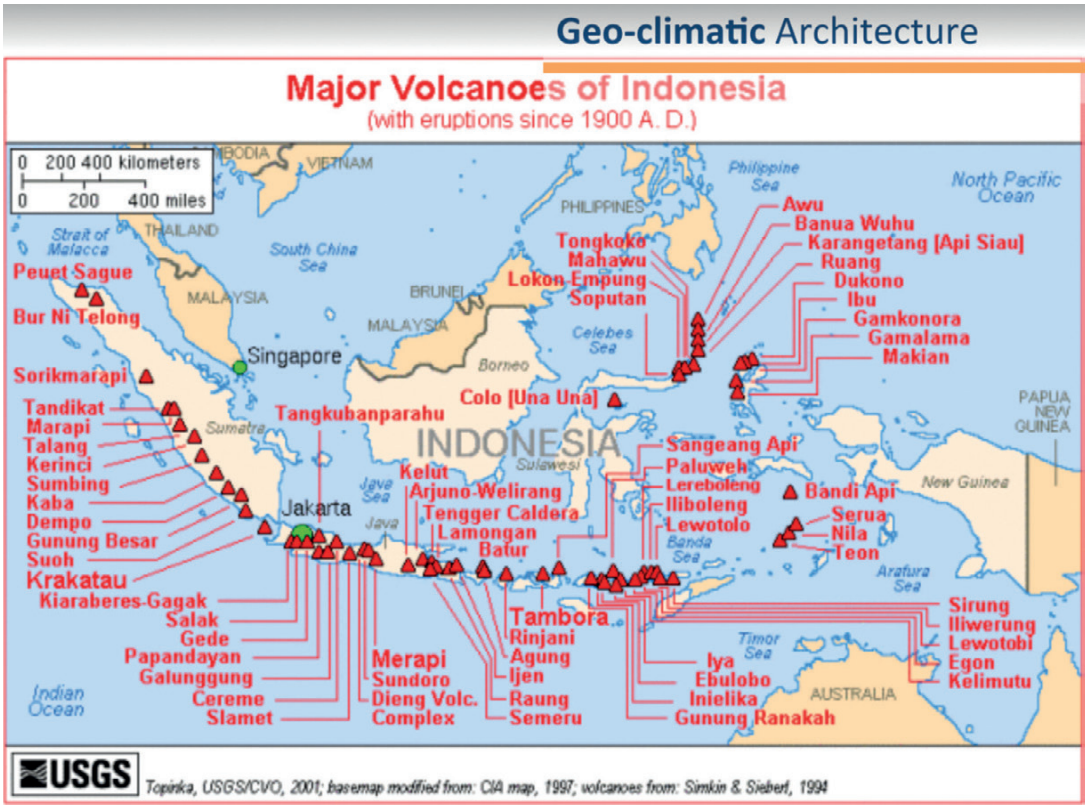
However, hundreds of aftershocks with various intensities were felt and hampered recovery efforts[6]. As a comparison, the earthquake in Yogyakarta, Indonesia, on May 27, 2006. The earthquake destroyed the walled house that was popular at that time. Structural strength, quality of materials and construction, and the processing and construction technique greatly affect the resistance to earthquake forces (Boen, 2006).

The earthquake was felt as far away as Jakarta, about 60 miles northwest of Cianjur, and in the nearby cities of Sukabumi and Bandung. Officials continued to assess damage in mid-December and reported significant to buildings and infrastructure (Fig. 3). Local emergency responders were supplemented by support from the government of Indonesia, the military, the Indonesia Red Cross, and hundreds of nongovernmental organizations from the area.

Indonesia is regularly affected by natural disasters, and its local constructive tradition has a relevant role in the survival of communities as a cultural identity. Therefore, post-earthquake investigations of the damage to wooden buildings due to the Java 6.3 Mw earthquake were carried out in Yogyakarta (Elnashai et al., 2007; Prihatmaji (et al., 2014) report the research results and verify the contributions of structural proportions to the level of damage on Joglo (one type of Javanese wooden building). Four levels of damage were categorized as follows: I) on the base joint of the side structure II) fatal on the side structure III) destroyed core structure, and IV) collapsed core structure. Instead, the only deterioration was found among the observed Joglos[7]. Furthermore, using teak wood, good carpentry work, well maintenance from residents, and relatively satisfactory cross ventilation contribute to the earthquake resistance properties of Joglo (Yahmo, 2007).

Recommendations for tangible and intangible values in Cultural Heritage

In Asia, building codes ensure resilience and compatibility with vernacular building practices and local materials. Following this aim, a damage assessment in post-disaster recovery should be based on the damage degree and methodology to recover and



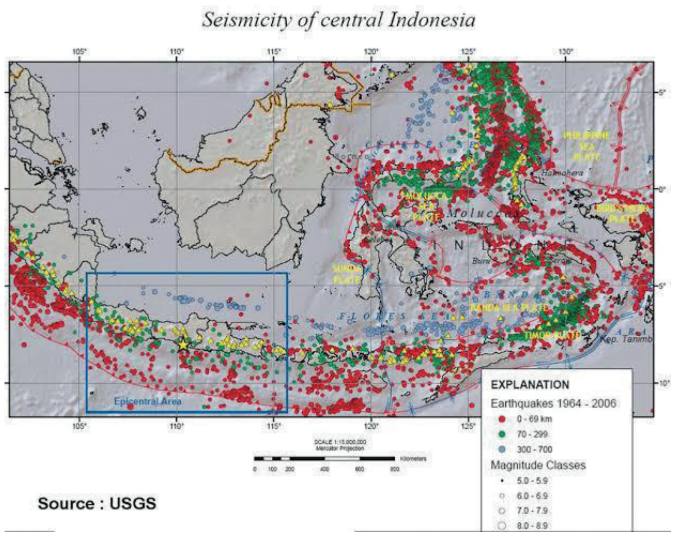


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Fig. 2
Pacific Ring of Fire: Volcanic Locations and Tectonic plate boundaries.

below
Fig. 3
Seismic Map of Indonesia, 2022 (Source: BMKG, 2023).

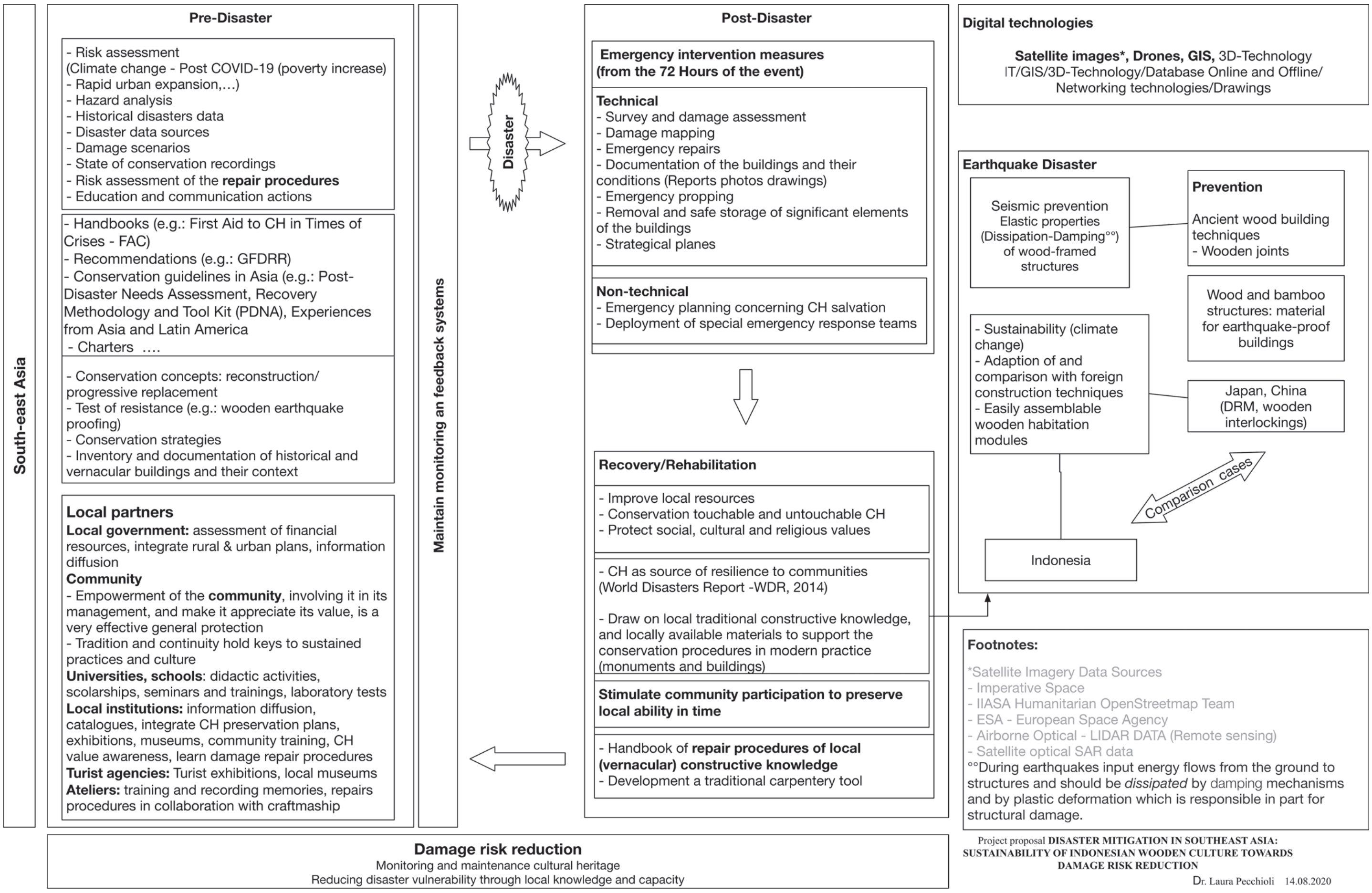

Fig. 4
Disaster Risk Management Schema (Source: Pecchioli, 2020).

repair the constructive system and the decorative apparatus. In the case of Indonesia, a periodical conservation strategy for painting and crafting wood could be considered the Guidelines on Cultural Heritage Technical Tools for Heritage Conservation and Management Conservation[8] and consolidation measures[9]. In addition, preservation requires the adoption and constant improvements of state-of-art science and knowledge involved in the interaction between scientists of different research fields (Fig. 4).

In the last ten years, different charters and guidelines in the context of the World Heritage Convention have been developed to foster a multidisciplinary approach. UNESCO recommends preserving cultural and natural sites of outstanding universal value as humanity's heritage for future generations. A relevant milestone relative to natural disasters was reached in 2010 with the Resource Manual on the Managing Disaster Risks for World Heritage: the UNESCO, ICCROM, ICOMOS, and IUCN published for the first time a guide for site managers requiring disaster risks management plans as part of an overall site management system (UNESCO, 2010).

Concerning the protection of wooden structures, the Final draft[10] for distribution to the ICOMOS members deserves to be mentioned for submission to the 19th ICOMOS General Assembly should be mentioned. It sought to apply the general principles of

the Venice Charter (1964), the Declaration of Amsterdam (1975), the Burra Charter (1979), the Nara Document on Authenticity (1994), and related UNESCO[11] and ICOMOS doctrines concerning the protection and conservation of the wooden built heritage. In particular, the Document aimed to update the Principles for the Preservation of Historic Timber Structures adopted by ICOMOS at the 12th General Assembly in Mexico (October 1999). The updating process began in Guadalajara, Mexico (2012), Himeji, Japan (2013), and continued in Falun, Sweden (2016).
Review of Post Disaster Recovery Needs Assessment and Methodologies, Experiences from Asia[12], and Toolkit (Bollin et al., 2017; Herbig et al., 2017a; 2017b; 2019; Budiono, 2004) represents a relevant framework relating to cultural heritage and dealing with Asia and reviews past methodologies and all actors in a toolkit in a recovery process. In addition, a handbook developed in recent years by ICCROM about creating a context-specific plan for on-site actions in emergency post-disaster is a milestone for First Aid (Tandon, 2018).
National Seminar of Disaster Risk Reduction of Strengthened Indonesian Resilience: Reducing Risk from Disaster carried out by Universitas Gadjah Mada and GNS Science New Zealand in Yogyakarta 2019. A program about preparedness was defined, especially for increasing tsunamis (Tsunami Blue Line Projects in Padang and Bengkulu). The Research Center for Disaster Mitigation of Urban Heritage (Rits-DMUCH)[13] has also tried to link the conservation of cultural heritage and disaster risk reduction by developing an International Training Course on Disaster Risk Management of Cultural Heritage. In addition, the National Board of Disaster Management (BNPB) Indonesia periodically, till 2022, carried out national seminars on the stakeholder role in disaster risk reduction in Indonesia.

Enhancing and preserving the historical knowledge and traditions

The timber construction knowledge throughout time spread worldwide and developed in all cultures and civilizations, overcoming all geographical boundaries. However, some vulnerabilities may be specific to some countries, monuments, and housing. These latter are due to the materials used in their construction or architectural design (Pecchioli, 2023b).
Indonesian vernacular architecture represents a vital building tradition and is precisely identified in the archipelago of Southeast Asia and some parts of the island. Stilts distinguish the houses by raising the living room floor, a very inclined pitched roof built in wood, and other organic materials. The typology of traditional dwellings is developed in response to the conditions of a hot and humid tropical climate.
Even conservation or rehabilitation choices without adequate reinforcement or mitigation of the risk may induce and increase the degree of deterioration. From this point of view, the community preserve and transfer to future generations the tradition and applying it with the proper *criteria* and materials. The huge advantage is that building an earthquake-resistant timber structure has cost efficiency and does not require a large amount of material and the accurate planning of essential connection details.
Valuable indications of their reliability and enabling a revival in restoration work are essential sources in analyzing and documenting the performance of local building materials used in the past. In addition, comparing the state of conservation before the disaster with the positive/negative responses due to the materials adopted adds relevant information about the construction procedures, allowing optimizations and

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Fig. 5
Typical housing model and building material used in Sumba, East Nusa Tenggara (Source: Prihatmaji, 2019)
below
Fig. 6
Javanese architecture of Joglo roof type (Source: Fauzi, 2014).

adjustments over time. Traditional Indonesian vernacular houses are commonly built on stilts, except in Java, Bali, and the south-eastern islands (Figg. 5-6). The raised floor allows the breeze to expel warm and humid tropical air, insulate the dwelling above the rainwater runoff, as well as will enable the construction of houses on rivers and the edges of wetlands to isolate and protect people, goods, and food from humidity (also to protect against malaria-carrying mosquitoes and termites for house materials).
According to the standards of a simple building (Budiono, 2004) is a structural system with piles, beams, and lintels carrying the load directly to the ground, with non-load-bearing walls in wood or bamboo. Traditionally, mortise and tenon joints[14] and wooden nails are used but with a preference for the latter. Wood and bamboo are now considered building materials due to their renewability and high earthquake resistance. They could be used for their sustainable features, compatible with various conservation choices, and contribute to climate protection.

Infrastructure resilience

Landslides globally cause loss of life and lasting damage to critical infrastructure. A significant rainfall or earthquake can trigger tens of thousands of landslides, implying losses from damage to transportation networks that inhibit disaster response . The result is cascading effects such as flooding and debris hazards. Despite their ubiquitous nature in many natural disaster scenarios, there is little integration of pervasive landslide impacts throughout their complete landslide disaster life cycle, including preparation, recovery, and mitigation. Key decision-making and resilience-building capabilities related to landsliding for a wide range of stakeholder partners and publicly served data results essential. Today advanced landslide forecasting is adopted for predictive models, satellite data, and ground observation, including the risk evaluation based on the hazard model and outputs combined with exposure and vulnerability data. We can especially cover a range of spatial and temporal scales relevant to stakeholder decision-making and response needs through an integrative empirical and mechanical modeling approach.
Indonesian urban development entails certain risks, such as the increasing exposure of goods and people to disasters. Rapid urbanization has offered benefits such as increasing prosperity through economic specialization, creating livable cities developed on diverse economic drivers with vibrant public spaces, and supporting more efficient public services. However, about 42% of the population is estimated to be exposed to natural hazards. This number will increase due to the growth of the urban population and the related transformation of the built and natural environment, as well as the expected effects of climate change and more widespread land subsidence. Model recommendations can be suggested to improve the resilience of road and bridge infrastructure:

- *The action of water brings about slope instability*, and erosion causes 'road slope failures', with the impossibility of designing cut slopes using ideal characteristics. The introduction of new design methods and characteristic rock parameters to develop solutions better suited to local conditions would be suggested[15];
- *Awareness-raising*: the topic of using risk maps and advanced information systems is relevant. An essential tool to identify critical points along the network to plan preventive interventions to improve resilience. This would then reduce infrastructure damage and post-disaster rehabilitation costs;

• Finally, the demand for increased pre- and post-disaster damage assessments should include more site-specific analyses[16].

Indonesia, a country highly prone to natural disasters, is committed to comprehensively addressing its impact on life and infrastructure. Accordingly, the government continues to work hard to improve specifications, guidelines, and practices to increase infrastructure resilience.

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Fig. 7
Working with locals to rebuild a wooden Sumba building to learn traditional carpentry and its traditions on IWWA 2019 Sumba (Source: Prihatmaji, 2019).
below
Fig. 8
Single-loaded wooden Tongkonan housing in Toraja (Source: Prihatmaji, 2017).

Traditional timber design and carpentry

The traditional knowledge systems as earthquake-proof construction, seem to show satisfying mechanical proprieties, which could play an essential role in Damage Risk Reduction. However, many traditional buildings could not withstand strong earthquakes, like Yogyakarta, which was built when construction standards and codes did not exist in Indonesia. Therefore, the Indonesian government systematically needed to characterize wooden architecture (Yatmo, 2007).
In 2019 Sekolah Tukang Nusantara (SETON-Nusantara Carpenter School, Universitas Islam Indonesia) held International Workshop on Wooden Architecture (IWWA) for a couple of days in Sumba, East Nusa Tenggara, Indonesia. SETON is a joinery study group that will collect and integrate traditional methods to produce suitable and appropriate ones and disseminate knowledge and skill to young carpenters, students, and people interested in traditional carpentry. IWWA 2019 rebuilt a traditional building in Praigoli village, Sumba. A single wooden building was successfully reconstructed with the cooperation of the local community. The traditional vernacular methods and cultural values are considered. The workshop aimed to learn craftsmanship and its traditions from actual construction by traditional communities towards earthquake-responsive buildings[17].
Governments can quickly identify key investment needs using remote-based damage estimations and generate inputs for more detailed assessments. The technical assistance supported by the Global Facility for Disaster Reduction and Recovery (GFDRR) has produced risk profiles, vulnerability and fragility assessments, and hazard modeling – all crucial information to build back better, increasing resilience to future disasters in the long term. In Central Sulawesi, this results in reconstructing buildings to contemporary seismic design standards, complemented by a capacity building program on seismic strengthening good practices (Fig. 7).

Wood frame buildings under earthquake load

Wood has been used as a building material for thousands of years and is still the subject of academic and professional research. The use of wood in constructing a house structure in earthquake-prone regions is considered one of the most critical and reliable building materials, as it is both renewable and highly resistant due to its properties (Fig. 8). In the post-earthquake reconstruction, it was less commonly used than other materials (iron, for instance). Still, its usage could be considered an anti-seismic system in the damaged buildings' reinforcements and other countries like Europe, not just Asia. It is documented that the insertion of wooden beams, used similarly to tie-beams, both in civil and in monumental buildings and as still visible inside masonry systems in archaeological contexts, provided a better cohesion for the masonries and lightweight partition walls (Bramanti, 2004; Giuliani, 2011).

Indonesia's entire system is a creative craft in pure wood joinery, with no nails used to join members, thus providing a looser connection to behave as a shock absorber during an earthquake. In particular, applying an earthquake-proof solution to these building materials would also be relevant in reducing risk management (Idham, 2011; Idham et al., 2018). The development of repair and strengthening methods for each specific Indonesian traditional wooden building selected is then distilled into a methodology and concrete solutions, considering the traditional community ideology of avoiding metal elements in their construction (Fig. 9). In addition, repair and reinforcement methods such as using compressed wood fasteners, adhesive treatments, and glued-in rod methods are evaluated (Prihatmaji et al., 2015).

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Fig. 9
Crafting Wall Panel for Toraja house (Source: Prihatmaji, 2017).

Conclusions and developments

After some wrong choices and policies in recent years and various natural and human-induced disasters, combining nature-based solutions with the vernacular constructive tradition system shows an adaptive behaviour. It is the right approach for reasoned preservation. On-site measures and coordination/management with the community define the approach and methods to reduce disaster risk through maintenance as a monitoring instrument. As a country exposed and vulnerable to catastrophes, Indonesia has strong vernacular wood-building techniques that can significantly reduce the risk of damage and help to preserve cultural heritage. In response to disasters, resistance, and dissipation, solutions like the techniques of wooden joints have been proven over the centuries, resulting in repairable on-site by the community. Adequate data collecting and appropriate information mining of Indonesian wooden buildings could be road-mapped and investigated gradually with all stakeholders' support.
Furthermore, workshops and training related to wooden buildings conducted periodically with collaboration among higher education or vocational school groups, carpenters, local communities, and related organizations provide unique opportunities to meet to improve knowledge, skills, and participation in preserving and restoring the oral tradition. Increased information could be integrated through monitoring, forecasts, real-time updates on evolving hazards, and post-event data collection to support rescue and recovery efforts and longer-term model improvement/validation. These efforts will improve situational awareness, disaster risk reduction, response, and resilience of landslide hazards relevant to scientific and stakeholder communities.
Recovery programs must be cross-jurisdictional, inter-organizational efforts involving line ministries, development partners, NGOs, communities, and private sector actors. Institutional arrangements should be established early, and global experience shows that it is 'good practice' to have a single agency coordinating and, in some cases, implementing the recovery strategy. This helps to coordinate multiple partners and financing sources, matching funding availability with community needs.

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[9] In particular, a paragraph Protective measures and interventions on immovable cultural heritage assets: to avoid the risk of degradation of original pigments and paint layers, appropriate descriptions of the materials will be laid down in the project for certain types of intervention on polychrome surfaces (painted, carved, sculptural).
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[12] <https://www.undrr.org/quick/11680>.
[13] <https://r-dmuch.jp/en/aboutus/>
[14] A mortise and tenon joint connects two pieces of wood or other material. Woodworkers around the world have used it for thousands of years to join pieces of wood, mainly when the adjoining pieces connect at right angles.
[15] The adoption of technical solutions to deal with steep slopes (such as soil nailing with the protection of the slope surface with geotextiles, wire mesh, or pile walls), the construction of effective drainage systems and extraordinary maintenance and monitoring for the most critical sites.
[16] Such as hydraulic analyses of bridge foundations and more frequent monitoring of critical cases.
[17] The next one is scheduled for August 2023.