Differences in the earthquake preparedness of low- and high-income countries: The cases of Panay island, Philippines and Shizuoka Prefecture, Japan

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Research Article

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Abstract

Panay island, Philippines and Shizuoka Prefecture, Japan are populated communities, highly vulnerable to earthquake hazards especially tsunami, and having recognized preparedness measures. This study differentiates their disaster management strategies as they vary in resources. It further compares their earthquake countermeasures to assess the level of compliance with the four priority areas of the Sendai Framework for Disaster Risk 2015–2030. The previous experiences of researchers as practicing geologist, seismologist, and disaster manager have reinforced the needed information that were gathered through on-site visit, in-depth interview with disaster managers, and data mining using the websites of government agencies and private media entities. The collected data were subjected to content and narrative analyses. Findings revealed that Panay has minimal resources, yet utilizing the synergy of national and local governments and collaborating with foreign institutions, the private sector, and civil society organizations have enabled it prepare for devastating earthquakes. The high-income Shizuoka prefecture invested in innovation, logistics, provision of incentives, and flexibility to achieve an advanced and a considerable earthquake preparedness.

1 Introduction

Most casualties of natural disasters come from developing countries (Gaiha et al, 2015) where many people live in poorly built houses situated in unsafe urban areas (Zorn 2017). Building collapse has killed about 60,000 people yearly since public construction often is of low quality. Building regulations have less impact because of inadequate capacity and corruption (Kenny 2012). The magnitude 7.8 Turkey-Syria earthquake on February 6, 2023 was a recent example. Petrequin & Wilks (2023) reported casualties at more than 52,000 while the 298,000 buildings were destroyed or left unfit for use. BBC (2023); Letsch (2023); Said-Moorrhouse (2023) revealed that more than 600 Turkish were investigated while 184 suspects were arrested for endemic corruption and involvement in shoddy and illegal construction methods.

High income countries such as Japan and New Zealand have enhanced community preparedness and strictly implemented seismic building codes. They have had lower death toll (Shapira et al., 2015), but suffered from greater economic losses at 67% (Centre for Research on the Epidemiology of Disasters and United Nations Office for Disaster Risk Reduction 2020). These trends have challenged both the low- and high-income countries brace against earthquakes to minimize human and economic losses.

The Centre for Research on the Epidemiology of Disasters and the United Nations Office for Disaster Risk Reduction through the Emergency Events Database (2020) noticed an increase in the number of reported disasters and their total deaths, total persons affected, and economic losses in the past 40 years (1980–2019). Earthquakes rank third of the nine leading types of disasters frequently affecting the planet. The top ten countries by occurrence of disaster sub-groups in the last 20 years (2000–2019) are China, USA, India, Philippines, Indonesia, Japan, Viet Nam, Mexico, Bangladesh, and Afghanistan. The six of 10 deadliest disasters are earthquakes. These are the M9.1 Indian Ocean event with tsunami in 2004; the

M7.0 Haiti earthquake in 2010; a M8.0 earthquake in Sichuan province, China in 2008; the M7.6 Pakistan earthquake in 2005; a M6.7 event in Bam district, Iran in 2003; and a M7.7 shaking in Gujarat, India in 2001. Earthquake follows flood, drought, and storm in terms of total number of people affected, yet it is the deadliest form of disaster accounting for 58% of total deaths. It also causes great damages to infrastructure.

Benchmarking can be an effective tool (Navarro et al. 2019; Ke et al. 2013) that can guide countries effectively prepare against earthquakes. Public administration scholars have endorsed this approach to local officials who can adopt best practices from typical local governments (Ki 2020).

How do some earthquake-prone countries prepare against seismic hazards? After the magnitude 9.1 disaster in 2004, Indonesia integrated disaster education program into the schools' curriculum (Aksa et al. 2020). The devastating magnitude 7.0 earthquake on January 12, 2010 in Haiti has stirred the government, non-governmental organizations (NGOs), and the religious sector to enhance coordination (DesRoches et al, 2011).

India developed a mobile application that enhances the preparedness level of a person and community by providing the latest earthquake information, actions to take, and seismic zones to users (Kolathayar 2019). The mainland China introduces disaster prevention and mitigation training to farmers (Lian 2021). Italy focuses on the mitigation of public buildings by assessing their structural safety and, when needed, designing and executing strengthening interventions.

Panay island, Philippines and Shizuoka Prefecture, Japan (Fig. 1) were the chosen sites of this study as these two large communities situated along the Ring of Fire have admired earthquake preparedness programs. Their similar level of vulnerability to earthquake hazards but differences in resources and technology have resulted to distinct yet effective countermeasures against the understood risks. Other regions in low- and high-income countries may model their earthquake preparedness.

Earthquakes generate 21% of recorded economic losses. Japan ranks third at $439 billion, which accounts for 35% of the Asian region's total economic losses from 2000–2019 (CRED and UNDRR 2020). The 2011 Great East Japan Earthquake and Tsunami has claimed 19,747 lives (Fire and Disaster Management Agency 2021). The total economic losses have reached US$152 billion (Disaster Management, Cabinet Office 2016), the highest figure in any disaster event on record. The Fukushima-Daiichi Nuclear Power Plant accident brought the 10-year costs for the plant demolition, loss satisfaction, decontamination, and radioactive waste storing that are roughly estimated at US$193 billion (Ministry of Economy, Trade and Industry 2016).

Huge earthquakes have repeatedly occurred in Shizuoka prefecture. A magnitude 8.0 earthquake may kill thousands, injure hundreds of thousands, damage millions of buildings, and leave the city devastated (Yanagawa et al. 2015). The prefecture prepares for the 'Big One' since 1976 and became the most "quake-ready" prefecture in Japan. The government's priority for disaster prevention policies can be seen in the mentality of residents (Osaki 2020).

The Philippines is among the low-middle income countries (The World Bank 2021) where the highest total number of deaths caused by disasters are recorded (CRED and UNDRR 2020). In Panay, one active fault, a trench, and a collision zone have the tendency to generate another destructive earthquake (PHIVOLCS 2019). Since this implies a need to maximize disaster mitigation and preparedness measures, Hall (2016) noticed that the local military unit based in the island has clearer parameters in utilizing civilian mechanisms for disaster response.

The Disaster Risk Reduction and Management Offices (DRRMOs), emergency response team, schools, a volunteer organization, and hospitals in Panay island were finalists and awardees in DRRM at the national level (Office of Civil Defense 2019; Rappler 2017). Its two earthquake monitoring stations in the provinces of Aklan and Capiz were model field station awardees. These distinctions recognize the island's investment in logistics, drills, and massive multi-hazard information drive.

Previous studies have compared the citizens' level of preparedness in low- and high-income countries that are highly susceptible to earthquakes. The relationship of preparedness against habitation, past experience, marital status, and home ownership was explored. One to two effective earthquake preparedness measures were highlighted while other studies identified the predictors of hazard preparedness such as individual risk beliefs and community and institutional factors. Several papers have surveyed the differences in emergency management systems of high-income countries, but none has compared them with those of low-income countries.

The purpose of this study is to compare the management strategies employed in earthquake preparedness on Panay island, Philippines and in Shizuoka Prefecture, Japan based on the four priority areas of the Sendai Framework for DRR 2015–2030. Specifically, it answers these research questions: What are the geologic factors that have increased their level of vulnerability to ground shaking, tsunami, and other earthquake hazards? What is the average recurrence period of destructive to disastrous earthquakes in Panay past 1600 and Shizuoka since the 15th century? How do these two communities that differ in resources shield their citizens against the possibility of another large earthquake? What are the management processes that have reinforced Shizuoka prefecture's massive resources and advanced technology to achieve the highest level of disaster mitigation and preparedness in Japan? How does Panay island maximize earthquake preparedness considering its minimal resources?

This paper covers only the mitigation and preparedness initiatives against seismic hazards in two populated and earthquake-prone communities in central Philippines and eastern Japan where the researchers had previously practiced seismology, geology, and disaster management.

2 Framework

The Sendai Framework for Disaster Risk Reduction 2015–2030 (2015) has four priority areas. Priority 1 requires policies and practices for DRRM be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics, and the environment. Such knowledge can be leveraged for the purpose of pre-disaster risk assessment, for prevention and mitigation, and for the development and implementation of appropriate preparedness and effective response to disasters.

In Priority 2, strengthening disaster risk governance in all levels for prevention, mitigation, preparedness, response, recovery and rehabilitation is necessary while fostering collaboration and partnership across mechanisms and institutions for the implementation of instruments relevant to disaster risk reduction and sustainable development. Priority 3 stresses public and private investment in disaster risk prevention and reduction. Priority 4 indicates the need to further strengthen disaster preparedness for response and recovery while empowering women and persons with disabilities.

3 Methodology

The experiences of the Japanese and Filipino researchers who practiced geology in Shizuoka Prefecture and seismology and disaster management in Panay respectively have made them familiar with earthquake sources that threaten these communities. They are also abreast with the earthquake hazards that pose danger to Panay and Shizuoka; the level of vulnerability of these areas to tsunami, ground shaking, earthquake-induced landslide, and liquefaction; and the implemented disaster risk reduction management programs and projects that aimed to reduce the impacts of earthquake hazards.

Data mining has reinforced and validated the knowledge and experience of researchers. The sources were websites of national government agencies, local government offices, and privately-owned media entities. The collected secondary data included the trenches and active faults that have generated large magnitude earthquakes on Panay island and in Shizuoka Prefecture and the historical earthquakes and tsunamis that have hit these places. The additional data on completed DRRM programs and projects in these communities were also sought. The accomplishment reports and updates posted in the official websites and social media accounts of public institutions were retrieved to supplement the collected data. Journal articles were used as supplementary references.

An in-depth interview with 10 disaster managers has supplied the full details of previously carried out DRRM programs and projects. The informants have clarified and validated the collected secondary data.

Triangulation was done through on-site visit in Shizuoka prefecture's state-of-the-art earthquake observation facilities, operations center, tsunami and tide gauges, and earthquake intensity meters. The same method was done on Panay island. Palmer & Rapport (2022) observed the significant contributions of on-site visits in learning. It mitigates impression management and enables visitors see things as they are (Nelson 2017). The handed Japanese reading materials have reinforced the series of onsite visit and orientation. These printed information were useful in familiarizing the prefecture's advanced earthquake prevention, mitigation, and preparedness measures.

To avoid bias, content and narrative analyses were done manually and individually to collate the gathered data. The differences in the outcome of individual analysis were resolved through online and group analysis. These methods have established the credibility of collected data.

The identified earthquake countermeasures in Panay and Shizuoka were finally grouped into four areas: (1) understanding disaster risk; (2) enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation, and reconstruction; (3) investing in disaster risk reduction for resilience; and (4) strengthening disaster risk governance to manage disaster risk. Using a checklist, the complied and unmet criteria in each area of the Sendai Framework for DRR 2015–2030 were identified.

4 Results

4.1.1. Understanding disaster risk

Scientific investigations have enabled Japan and the Philippines to detail and widely disseminate to citizens the risks that threaten their communities. The Philippine Institute of Volcanology and Seismology or PHIVOLCS (2021) utilizes its website, printed materials, free software applications, and lecture series to circulate to the public the three earthquake sources that pose threats to Panay island. The West Panay Fault transects its western part and can generate a magnitude 7.0 event. There is also an offshore Collision Zone in Mindoro Strait, a sea northwest of the island. The Negros Trench in Sulu Sea, south of the island, can trigger a magnitude 8.0 earthquake. On August 13, 2022, a Mw5.1 tectonic earthquake was triggered near the Negros Trench. Its offshore epicenter was located in Anini-y, Antique (Fig. 2). The felt ground shaking ranged from intensities I to IV.

The residents are informed that Shizuoka prefecture in eastern Japan is prone to catastrophic earthquakes that might be generated along the Nankai Trough (Fig. 3). Historical records show the recurrences of earthquakes in this region with M ~ 8 or greater (Table 1). The Fujikawa-Kako Fault Zone (FKFZ) extends in the north-south direction about 20 km, from the mouth of Fujikawa River (near the eastern tip of the segment E in Fig. 3) to the southwestern foot of Mount Fuji (Shizuoka prefecture Department of Emergency Management 2010, 2016).

The coastal lowlands of Shizuoka prefecture are susceptible to liquefaction. The reclaimed lands around the Shimizu Port on the northwestern coast of the Suruga Bay and Lake Hamana in the westernmost of Shizuoka prefecture are also subjected to liquefaction that the Nankai Trough earthquake may cause (*e.g.* Shizuoka prefecture GIS https://www.gis.pref.shizuoka.jp/). Meanwhile, the coastal areas in Shizuoka from Atami in the northeast to Kosai in the southwest are tsunami-prone.

Large earthquakes and tsunamis that hit Shizuoka prefecture are documented in historical records from 15th to 19th century (Table 1; modified after Igarashi, 2010). The Tokai earthquake, which corresponds to the rupture of the segment E (Fig. 3) is an earthquake of disastrous proportion that occurs in Shizuoka prefecture every 100 to 500 years (Shizuoka prefecture Department of Emergency Management 2010, 2016).

The focal region of the Nankai Trough is divided into six segments—A, B, C, D, E and Z (Fig. 3). Major portions of Shizuoka prefecture belong to segment E. The recent event in segments A and B was the 1946 Showa-Nankai earthquake (M 8.0), the 1944 Showa-Tonankai earthquake (M 7.9) in segments C and D, and the 1854 Ansei-Tokai earthquake (M 8.4) in segment E. The largest historical event along the Nanaki-Trough is the 1707 Hoei earthquake (M 8.7), which ruptured all segments Z and A to E. It can be observed that a seismic interval in segment E at more than 150 years is long enough for an energy buildup to cause another large Tokai earthquake. Until 2016, the framework of the earthquake countermeasures in Shizuoka had been relying mostly on an assumption of a possibility of imminent prediction of the Tokai earthquake (Shizuoka prefecture, 2019). Government offices have been widely circulating to the public the exposure of their prefecture to risks.

Japan has adopted flexibility in earthquake preparedness. After the Mw9.0 Great East Japan Earthquake off the Pacific coast of Tohoku in 2011, the policy for disaster management was updated. It recognized the possibility of infrequent largest (Mw ~ 9.0) earthquake and difficulties in its imminent prediction.

Present earthquake countermeasures in Japan have been classified into two different categories, levels 1 and 2. The level 1 earthquakes are frequent disastrous events that have been occurring in the historic time, such as the Tokai earthquake (< magnitude 9.0). The level 2 earthquakes are infrequent largest events such as the 2011 Tohoku earthquake at magnitude 9.0. In 2017, the central government concluded that the imminent prediction is not possible at present. It, then, changed the strategy for response to Nankai Trough earthquake (Fig. 3) considering large uncertainties in the pattern, size, and timing of the fault rupture.

In 2013, Shizuoka prefecture announced the fourth damage estimate for the level 2 Nankai-Trough earthquake, which is much larger than that of the Tokai earthquake. The estimated damage that a M8.0 earthquake might cause are further strengthened with multi-hazard, tsunami inundation, and tsunami height maps. The source area of tsunami will be the Suruga and Nankai Troughs (Shizuoka prefecture Department of Emergency Management 2010, 2016).

Shizuoka prefecture has published a GIS system, which is constructed on a web-mapping platform like Google Map to make it user-friendly and easier to understand. It includes various types of datasets, such as historical disaster records and tsunami inundation areas, projected inundation, seismic intensity, liquefaction, and landslides due to the Nankai-Trough earthquake (https://www.gis.pref.shizuoka.jp). The GIS system will enable communities understand the risks that an earthquake and its natural hazards may cause.

The residents are well-informed that the prefecture is prone to catastrophic earthquakes that the Nankai Trough may generate (Fig. 3). Most Japanese mothers having children with allergic diseases stock in their homes a range of allergen-free food ready for a one week consumption (Hirase et al. 2019; Fukuie et al. 2014).

The capital cities and municipalities of the four provinces in Panay have several coastal villages susceptible to liquefaction. The western, southern, and from south-southeastern to the southeastern coastal areas are prone to 6–13 meters high tsunami. These are the coasts of Antique and Iloilo provinces (PHIVOLCS 2019).

Five damaging earthquakes have hit Panay island in the past four centuries (Table 1). The most recent one struck on June 14, 1990 (Bautista et al. 2011), 32 years ago. The average recurrence period of a magnitude 7.0 earthquake in Panay is every 92 years.

Atando (2018) has documented the earthquake preparedness and mitigation projects in Panay from 1990–2018. The United Nations Development Programme (UNDP) and Australian Aid for International Development (AUSAID) have funded the island's multi-hazard mapping project in 2009. Antique and Iloilo in Panay were two of the 27 high risk provinces that benefitted from this project. The produced multi-hazard maps are accessible and downloadable in government websites while the printed and soft copies were furnished to local government units (LGUs), which were briefed to integrate them into land-use planning and public policies.

The Australian government sponsored in 2010 the assessment of buildings in a portion of the Jaro district in Iloilo City and simulated the impact of two damaging earthquakes at magnitude 6.3 and 8.1. The number of casualties and percentage of collapse among building types were estimated. The project collaborators were national government agencies, Geoscience Australia, University of the Philippines (UP), and Iloilo City local government.

Various collaborative projects have advanced the country's facilities and human resources. These led to a *Lingkod Bayan (*Public Servant) award in 2010 to former PHIVOLCS director (Dr. Renato Solidum) for gaining the support and confidence of external funders in the monitoring and mapping of geohazards at little to no cost to the Philippine government. He now heads the science department.

Capacity building trainings and information education and communication (IEC) campaigns became frequent since 2011 right after the passage of the Philippine DRRM Act of 2010. PHIVOLCS has collaborated in 2016 with the Geological Survey of Japan (GSJ) and the National Institute of Advanced Industrial Science and Technology (AIST) to develop the copyrighted and patented FaultFinder web application. This app shows the barangays (villages) transected by active faults and automatically measures the distance of a user to the nearest active faults. It enabled people to know the threats.

GeoRisk Philippines has come up in 2019 with the HazardHunterPH tool to generate indicative hazard assessment reports on the user's specified location. Individuals, property owners, buyers, land developers, and planners can assess the vulnerability of a community to seismic, volcanic, storm surge, severe wind, flood, and landslide hazards. The threatened critical facilities can also be identified. This tool is a multi-agency initiative of the country's science, environment, defense, and education departments with the assistance of Japan's GSJ.

The Philippines shares data to the world. It cooperates with international scientific communities such as Asian Seismological Commission, GFZ German Research Center for Geosciences, Japan Meteorological Agency, among others. The country regularly joins the Exercise Pacific Wave.

4.1.2. Strengthening disaster risk governance to manage disaster risk

PHIVOLCS has trained about 100 public and private employees in Panay since 2012 on mainstreaming DRR into the local development planning process, emergency preparedness, and contingency planning. Trainees use the locally-developed Rapid Earthquake Damage Assessment System (REDAS) software in simulating earthquakes, assessing damages, and identifying multi-hazards in local communities. This software is given for free to trainees and has features of a commercial Geographic Information System. PHIVOLCS and beneficiaries agree on the sharing of training expenses.

Local governments involve various sectors in crafting their 6-year disaster plans. A full-time manager should lead the DRRM office at local levels. The Defense secretary chairs the National DRRM Council involving government, civil society, and private organizations that engage in disaster preparedness, prevention and mitigation, response, and rehabilitation and recovery. Through the OCD, organizations are urged since 2006 to participate in the quarterly nationwide earthquake drill, which was done simultaneously starting March 1, 2012. Schools join at least once a year. The NDRRMC's annual *Gawad Kalasag* Award honors local governments, institutions, volunteer groups, and individuals that have greatly contributed in implementing DRRM programs that shield high risk communities against hazards, addressing their vulnerabilities, and coping with disasters (Atando 2018*)*.

In few areas, informal settlers along flood-prone rivers were relocated. This move has mitigated losses and rehabilitated polluted rivers. In Panay, the Iloilo-Batiano River Development Project was a national awardee *(Galing P*ook) in 2018. The initiative has addressed since 2011 the informal settlements, siltation, water pollution, encroachment, and illegal cutting of mangroves along the river. The collaborators were private sector, national government, and civil society organizations. More than 50,000 residents from 35 barangays (villages) along the Iloilo River alone have benefitted from this project (Santiagudo 2018).

Several types of drills for disaster management have been operated in Shizuoka prefecture. The most major one is the general disaster drill, which is held during the *Bosai* Week that includes the annual *Bosai* Day. *Bosai* in Japanese means 'disaster prevention', and the *Bosai* Day is the date of the Great Kanto Earthquake on 1st September, 1923. Every national governmental agency, local government, and other public institution conduct the drill to establish the framework of local disaster management, and to build public awareness (Shizuoka Prefecture 2021).

The headquarters and branch offices of Shizuoka Prefecture independently conduct the general map exercise every January to operate the earthquake countermeasures (Shizuoka Prefecture 2020). All officers acquire and validate the emergency operation skills. They confirm and reinforce collaboration with the national government and prefectural municipalities, which began since 2002 following the Great Kobe Earthquake on 17th January, 1995.

In the municipalities of Shizuoka, many voluntary systems for disaster prevention are organized. They conduct the local disaster drill every first Sunday of December (local *Bosai* Day) to prepare for unexpected earthquakes. The drill started since 1983, following the Japan Sea Earthquake with tsunami on 26th May, 1983. Around 20% of the total population including elders and middle and high school students joins the local disaster drill (Iwata 2020).

The central government of Japan has been developing legal systems to upgrade buildings and houses against damaging earthquakes. For example, Japanese residents who seismically retrofitted their houses from April 1, 2006 to December 31, 2008 can deduct 10% of its cost from income tax. The maximum limit is at 200,000 yen. Meanwhile, the Japanese who completed seismic retrofitting of their residences including rental houses business from January 1, 2006 to December 31, 2015 deduct the fixed assets tax by half in those periods (Shizuoka prefecture Department of Emergency Management 2010, 2016).

4.1.3. Investing in disaster risk reduction for resilience

Two national laws enacted in 1991 and 1996 allowed each LGU in the Philippines to reserve 5% of its annual budget for calamities. However, this budget could be spent only during and after the disaster. Preparedness and mitigation were not prioritized. When a landmark legislation in 2010 allowed LGUs to spend 70% of calamity fund for pre-disaster activities, local officials started acquiring logistics. They invited experts from national government agencies to give lectures and evaluate drills. The country observes the national disaster resilience month every July (Medina 2017).

The Association of Structural Engineers in the Philippines (ASEP), Japan International Cooperation Agency (JICA), and Japan Science and Technology Agency (JST) have assisted PHIVOLCS in 2014 to publish “How Safe is my House?” Reliable and easy-to-follow guide in constructing earthquake-resistant small buildings made of concrete hollow blocks are illustrated. A group of architects and engineers were trained on how to replicate this activity at the grassroots level.

IECs for disaster managers in tsunami-prone coastlines were done. The central and local governments pooled their resources when a Community-Based Early Warning System (CBEWS) for Tsunami Project did a tsunami drill in Barangay Botbot, Pandan, Antique in August 2016. Other coastal LGUs were invited to witness this activity that must be duplicated in their areas.

The national government has devised in 2014 the LGU Disaster Preparedness Journal: Checklist of Minimum Actions for Mayors. It prescribes the structures and systems, policies and plans, building competencies, and equipment and tools that local officials must comply (Dariagan et al. 2021). An updated version was launched in September 2019 (DILG, 2021). The Philippine government has just ratified the Paris Agreement on Climate Change to assist the other 133 parties in developing and implementing sustainable solutions toward a greener, more sustainable future for the planet (France Embassy in Manila 2021).

Shizuoka prefecture has been promoting the Action Program 2013 to reduce presumed fatalities by 80% in the next 10 years, following the catastrophic damages from the 2011 Tohoku earthquake. The program includes three main countermeasures: (1) upgraded tsunami countermeasures, (2) response for ultra-widespread disasters, and (3) countermeasures for compound and consecutive disasters. The upgraded tsunami countermeasures are building and reinforcing sea walls for level 2 tsunamis; updating evacuation plans and drills; and building more tsunami evacuation facilities such as tower, deck, and mound.

The 2,279 billion yen (US$20B) Earthquake Preparedness Projects were achieved from 1979 to 2015. The components included the rescue ship and helicopters; shelters and evacuation routes; firefighting facilities; earthquake-resistant hospitals, schools, and social welfare facilities; water gate and other facilities for avoiding tsunami hazards; landslide countermeasures; emergency transportation routes; communication facilities; other grant-in-aid to cities and towns; and disaster mitigation center equipped with reliable communication network.

The central and local governments of Japan have been promoting the development of legal systems for pre-disaster countermeasures and post-disaster aids. For example, Shizuoka prefecture offers subsidized charges for assessment of buildings to damaging earthquakes. Safety of the buildings are classified into three categories depending on probability of collapse during an earthquake. Then, the owners of high-risk buildings are informed so that they can upgrade the buildings with subsidized charges from the government. The establishment of four local disaster prevention bureaus highlighted the effective disaster management system in Shizuoka prefecture. The project "TOUKAI-0", in cooperation with cities and towns, raised awareness about the importance of making earthquake-resistant wooden houses. This massive information drive aims to make 95% of houses earthquake-resistant until 2020 and to grant subsidies to 18,576 wooden houses for seismic retrofitting in March 2015 (Shizuoka prefecture Department of Emergency Management 2010, 2016).

4.1.4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction

The magnitude 7.1 event in Panay in 1990 has prompted the government to set up earthquake monitoring stations on the island since 1993 (Table 2). It is the only island in the country with three staff-controlled seismic stations each manned by one resident seismologist and equipped with 24 hours digital earthquake monitoring system. One satellite-telemetered seismic station was added recently. The central government funds the building and equipment while the local government or a private individual donates the land.

JICA has upgraded the nation's earthquake and tsunami monitoring systems into digital. It sponsored the Japan-based trainings in previous years. Germany, Chinese Taipei (Taiwan), and China also invite Filipino seismologists to undergo short-term trainings (PHIVOLCS 2022).

Tsunami sensors were setup in Anini-y and Culasi in the province of Antique, western part of the island. The country's science department and Japanese government provided financial and technical assistance while PHIVOLCS installs and maintains the equipment. The central office in Metro Manila receives real time data from these sensors. It will activate the tsunami sirens put up in the vulnerable provinces of Antique and Iloilo in time of an impending tsunami.

The national government funded the Dynaslope project that installs landslide sensors since 2013 in six communities in the provinces of Iloilo and Capiz. The central government installs the equipment and issues alert levels to local officials and villagers when the monitored cracks are alarming. Local officials and the communities take care of the instrument and interpret advisories. The project collaborators were University of the Philippines, local governments, and organized local communities. The implementation was outsourced to make this project more efficient.

JICA, JST, and the National Research Institute for Earth Science and Disaster Resilience (NIED) have expanded Panay island's online earthquake intensity monitoring system. The LGUs supply power and internet connectivity while PHIVOLCS sets up and maintains the intensity meters. Data are sent to Manila in real time.

Earthquake information are posted in PHIVOLCS website 15 minutes after the event. Most recent data are likewise disseminated through short message service (SMS), Facebook, Office of Civil Defense, and media entities.

The Office of Civil Defense builds the capacity of local governments' DRRM offices. It leads the Regional DRRM Council members in the response and rehabilitation stages. After Typhoon Haiyan, it tapped the Department of Public Works and Highways (DPWH) in building large evacuation centers equipped with facilities. These structures became quarantine facilities during the outbreak of COVID-19 pandemic from 2020 to early part of 2022. Switzerland's Interchurch Aid HEKS has also funded three additional evacuations centers in Capiz.

The DOST and Chinese Taipei (Taiwan) have been funding the country's Global Positioning System (GPS) Project to determine the direction and velocity of the slow-moving Philippine islands toward the highly contested South China Sea. Data are also useful for earthquake prediction and post-event analysis. In 2018, a continuous GPS system was installed (Atando 2018).

Since putting up community centers for the promotion of public awareness on disasters in Panay require massive funds, each meteorological, seismological, and volcanological observatory stations has absorbed this function. The state's Disaster Information for Nationwide Awareness (DINA) Project has produced audio-visual presentations that discuss what to do before, during, and after the earthquake, tsunami, tropical cyclone, landslide, flood, and volcanic eruption. The video is available online.

Shizuoka prefecture has a Governmental System of Earthquake Research comprised of university professors and specialists from government offices that analyze recorded data and issue prediction or warning. It has also organized the academic committee for disaster and nuclear power to examine planning, coordination, formulation, and public relations for the policies. Since 2016, an assessment of the Nankai-Trough earthquake, which is classified as a level 2 event has been under operation rather than the imminent prediction of the Tokai earthquake. The assessment of the Nankai-Trough earthquake includes seismic activities in segments Z and A-E (Fig. 4). The committee monitors monthly the occurrences of small (M6.0–7.0) earthquakes and changes in strains observed at the terrestrial stations within Shizuoka prefecture. Considering the difficulties and uncertainties in prediction, the committee judges whether or not to issue warnings for the great Nankai-Trough earthquake.

Table 2 summarizes the permanent observation systems for earthquake and relevant phenomena that Shizuoka prefecture operates. It has a total of 494 monitoring facilities in 20 categories such as strain, earthquake, seafloor crustal movement, among others. The Japan Meteorological Agency (JMA) and Shizuoka Prefecture share responsibilities in the installation of these facilities.

The Permanent Ocean Bottom Seismograph (OBS) system is first in the world to observe submarine seismic activities continuously through an earthquake observation network on the sea bottom off the shore of Omaezaki. It is installed right above the earthquake nest of offshore Tokai. This system was installed in August 1978 and started its full operation on April 1, 1979. Data generated are transmitted by coaxial cable to the relay station and then to Earthquake Phenomena Observation System (EPOS) using dedicated telephone line for continuous monitoring.

Earthquake data generated from the Sagara Seismic Station are relayed to JMA Tokyo headquarters in real time via the dedicated telephone line. The Kakegawa Strainmeter Station detects micro-volumetric changes of rock beds accompanied by crustal activities. It plays a crucial role in the observation and prediction of the anticipated Tokai earthquake. The Shimizu Tidal Station and the Huge Tsunami gauge-Pressure Type Stations are some of the several tsunami-monitoring stations around Japan. The Dense Ocean Floor Network System for Earthquakes and Tsunamis (DONET) off the shore of Kii peninsula became operational since 2011. Offshore GPS tide gauges installed off the shore of Omaezaki have been playing a key role for tsunami observation and warning since 2007. Warnings, advisories containing the tsunami grade, area to be affected, and estimated time of arrival are issued to disaster reduction organizations, broadcast media, and general public right after a tsunami earthquake.

In case of a severe natural disaster, families whose houses were severely damaged are provided with support funds to reconstruct by themselves their livelihoods (Shizuoka Prefecture, 2019). Considering the future occurrence of the Nankai-Trough earthquake, renovation of communities is promoted to minimize the damages and losses (Shizuoka prefecture Department of Emergency Management 2010, 2016). Examples of the activities include the integration of tourist facilities and tsunami evacuation tower, development of inland/upland industrial areas, establishing disaster-related treaty between local companies and communities, and extension of regional traffic networks. The pre-disaster reconstruction will enhance disaster preparedness and sustainability of local communities.

5 Discussion

A disastrous earthquake hit Panay island in 1990, but the Negros Trench and Collision Zone have no documented magnitude 7.0 events since the Spanish colonizers discovered the Philippines in 1521. Shizuoka prefecture has been quiet for 167 years. These situations manifest energy buildup and might be great once released during an earthquake. Hainzl et al. (2000) argued that large earthquakes are preceded by seismic quiescence, a period on average of reduced frequency of earthquake occurrences. The longer the duration of this period, the larger on average is the subsequent earthquake.

Their earthquake preparedness measures comply with the United Nations Sustainable Development Goals numbers 11 (make cities and communities sustainable) and 17 (enhance partnerships for the goals). They also conform with the four priorities of the Sendai Framework. In the Philippines, however, the weakness in priority area 2 is the failure to provide incentives to ensure the citizens' high level of compliance with laws and regulations; further promotion for disaster risk insurance in priority area 3; and establishment of community centers for the promotion of public awareness in priority area 4.

The proposed framework in earthquake preparedness for low- and high-income countries (Fig. 4) emphasizes that the known exposure to vulnerabilities and risks challenge communities to prepare for co-seismic uplift/subsidence, intense ground shaking, rupture, liquefaction, landslide, tsunami, and fire. However, response is dependent on resources. Panay island sought the assistance of high-income countries, private individuals, entities, and local volunteer groups in doing pre- and post-calamity drives. Tapping the aid that collaborators offer has made it prepared against earthquakes regardless of minimal resources. Collaboration, networked governance, and synergy through inter-agency pooling of resources can turn low-income countries resilient to disasters. Limited capability is not a hindrance to invest in preparedness as donors transfer technology while funding various DRRM projects. The absence of support from developed countries and partners might have lowered the capability of developing communities in Panay to mitigate natural hazards. The participation of stakeholders in policy formulation and regular drills have complemented the aid from high-income countries.

Shizuoka Prefecture continuously innovates its earthquake and tsunami monitoring system. It prioritizes earthquake preparedness and mitigation through substantial investment in the resiliency of infrastructure, provision of incentives to citizens, earthquake research, information drive, and advanced monitoring facilities. Massive resources are spent to acquire logistics necessary for the response and rehabilitation stages.

The 2011 Tohoku earthquake and tsunami has made experts to integrate the contingency approach in disaster preparedness. Seismologists now recognize the possibility of infrequent largest earthquake at magnitude 9.0 as it happened in 2011. The prefecture prepares for more catastrophic earthquakes through reinforcement of innovation with flexibility in preparedness. Scientists need to match their actions with the situation. Disaster management involves not only agility but also innovation and adaptability.

Panay island in the Philippines and Shizuoka prefecture in Japan challenge the local governments in low-, middle-, and high-income countries vulnerable to natural hazards to utilize innovative means in intensifying their disaster mitigation campaign. A high level of preparedness lowers the destruction to properties, loss of lives, and economic damage. Effective yet efficient disaster management strategies will leverage insufficient resources into ample disaster preparedness.

6 Recommendation

In Panay, an assessment of all structures is vital prior to the issuance and implementation of orders such as retrofitting and demolition. To fully comply with priority area 2 of the Sendai Framework, incentives may be provided to ensure compliance with the building code and land use plan. It will motivate relocation and demolition or retrofitting of structures. If funding is unfeasible, strict imposition requires penalties for violators and soft law enforcers.

Most Filipinos do not prize the benefits of insurance (Sun Life 2017). Bundling earthquake insurance with fire insurance and others which has high uptake in the population is effective as proven in other countries. This may lead to full compliance with priority area 3. Business establishments need to participate in earthquake drills. The annual business permit may only be renewed if the firm has joined in fire and earthquake drills once a year.

PHIVOLCS has to expand its tsunami monitoring network. Regular preventive maintenance will assure the uptime of limited monitoring equipment. Network expansion and a backup instrument will make operations running despite the breakdown of primary equipment.

Educating and training all tsunami-and landslide-vulnerable villages will lessen future casualties and convince them to relocate. Local authorities are expected to strictly implement land use plan while providing relocation sites to landless inhabitants.

Shizuoka prefecture is well prepared for another catastrophic earthquake. It is a model to high-income, yet earthquake-prone countries. The efforts have to be sustained while the people remain patient in preparing for infrequent large magnitude earthquakes. Complacency may reduce the level of preparedness. Japan recovers faster from disastrous events, but further research on linking the pattern of recorded data prior to large earthquakes may lead to the discovery of a method for earthquake prediction.

Declarations

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Conflict of Interest

The authors declare that they have no conflict of interest.

Availability of data and material

The detailed data and materials used as bases in completing the manuscript are available upon request.

Code availability

Author contributions

The two authors contributed to the study conception and design. Material preparation, data collection, and analysis about Panay Island, Philippines were performed by [Asst. Prof. Ramil Atando]. On the other hand, the material preparation, data collection, and analysis about Shizuoka Prefecture, Japan were performed by [Dr. Daisuke Sugawara]. The first draft of the manuscript was written by [Asst. Prof. Ramil Atando] while [Dr. Daisuke Sugawara] commented on the previous version of the manuscript. The second draft and final manuscript were written by [Prof. Ramil Atando] incorporating the major suggestions by [Dr. Daisuke Sugawara]. All authors read and approved the final manuscript before its submission to the journal.

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Tables

Table 1. The historical earthquakes that hit Panay island (Bautista *et al*. 2011) and Shizuoka prefecture (Modified after Igarashi, 2010)

Panay Island, Philippines		Shizuoka Prefecture, Japan	
Year	Magnitude	Year	Magnitude
1621	M7.2	1498	M8.4
1787	M7.4	1707	M8.7
1887	M7.3	1854	M8.4
1948	M8.2	1944	M7.9
1990	M7.1		

Table 2. Observation Facilities in Shizuoka, Japan (Shizuoka prefecture Department of Emergency Management 2010, 2016) and Panay, Philippines (PHIVOLCS 2022) as of April 2022

Category of Observations	Shizuoka Prefecture, Japan			Panay Island, Philippines
	Facilities	**Telemeters**		**Facilities**
Strain	29	29	(24)	0
Earthquake	114	113	(98)	3 + 1 satellite-telemetered
Tilt	42	42	35	0
Tide (Tsunami)	9	9	(9)	0/downtime
Self-Potential	4	4	(0)	0
Geomagnetism	24	19	(0)	0
Ground Water Level	16	16	(12)	0
Groundwater	1	1	(0)	0
Radon	2	2	(0)	0
Contraction	4	3	(2)	0
Gravity	1	1	(0)	0
GPS	232	123	(0)	13
Laser	1	1	(0)	0
Electromagnetic Total Force	2	2	(0)	0
Geomagnetic Total Force	1	1	(0)	0
Soil Temperature	1	1	(0)	0
Water Temperature	1	1	(0)	0
Pore Water Pressure	3	0	(0)	0
Dissolved Gas	3	3	(3)	0
Seafloor Crustal Movement	4	4	(4)	0
Landslide	-	-	-	6
TOTAL	**494**	**375**	**(192)**	**23**

Figures

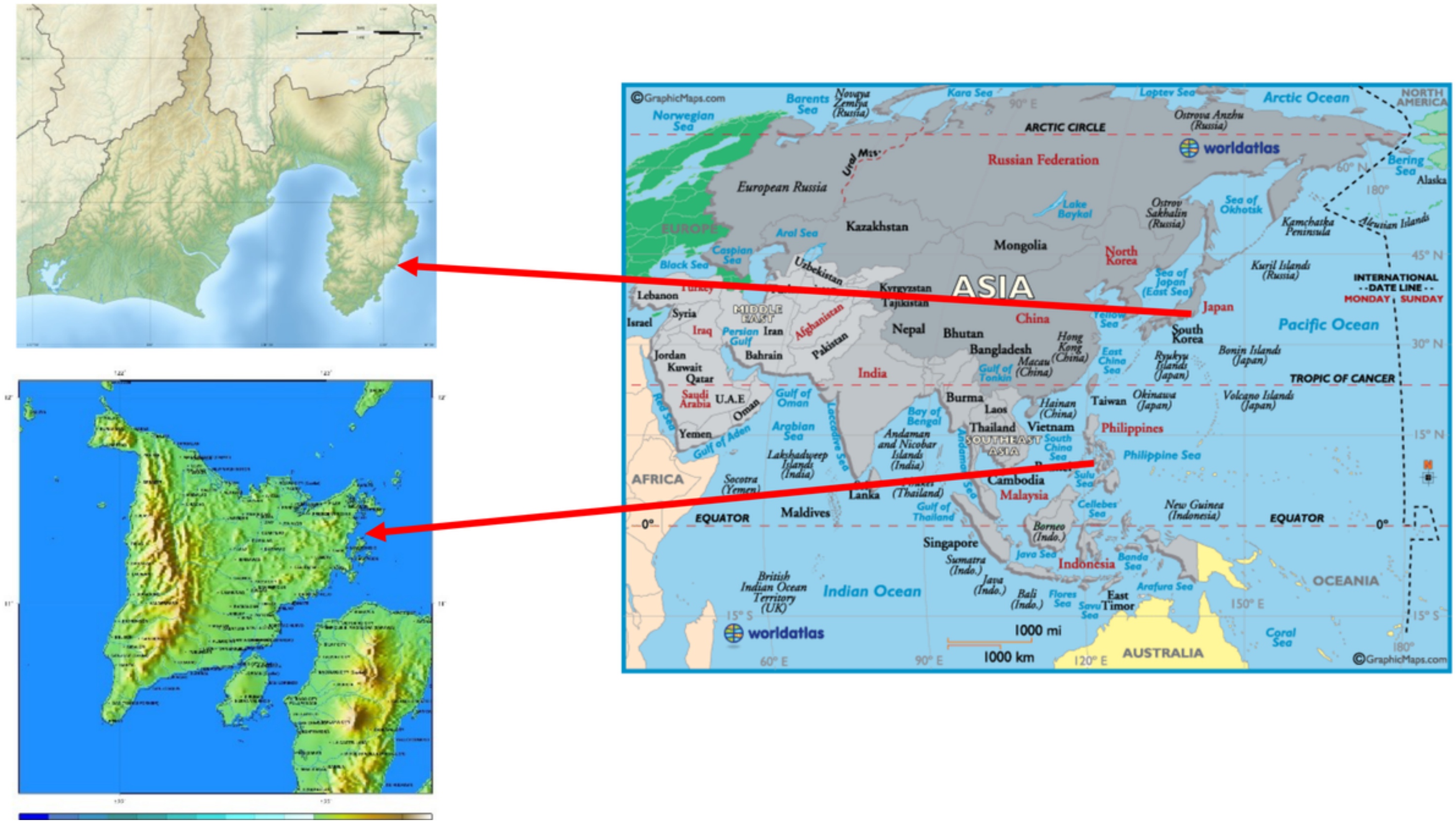

Figure 1

Panay island, Philippines and Shizuoka prefecture, Japan (References: *Natural Hazards* and by Flappiefh - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=52998432)

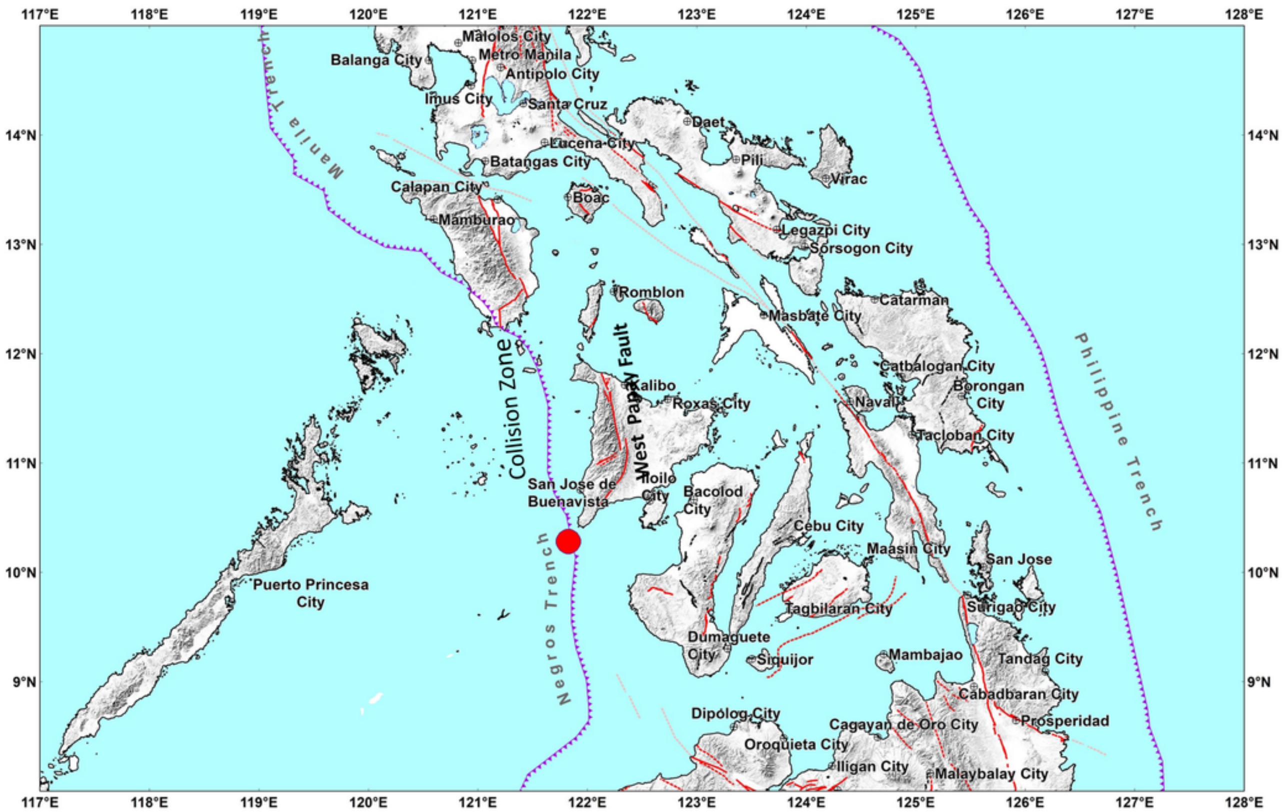

Figure 2

Earthquake generators on and adjacent to Panay island (Philippines), and epicenter of the August 13, 2022 Ms 5.1 event (Source: PHIVOLCS 2022)

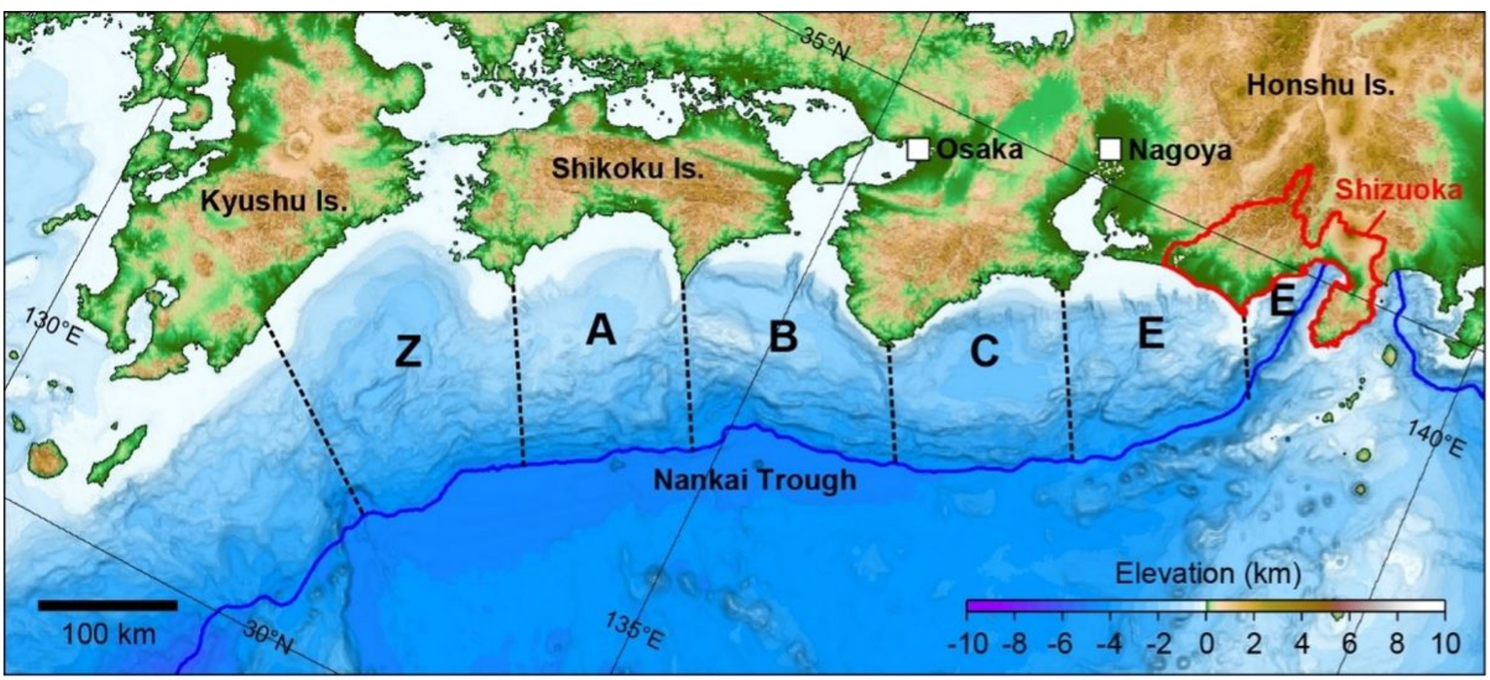

Figure 3

Seismic segments of the Nankai-Trough Earthquake (Z and A-E) and the location of Shizuoka prefecture

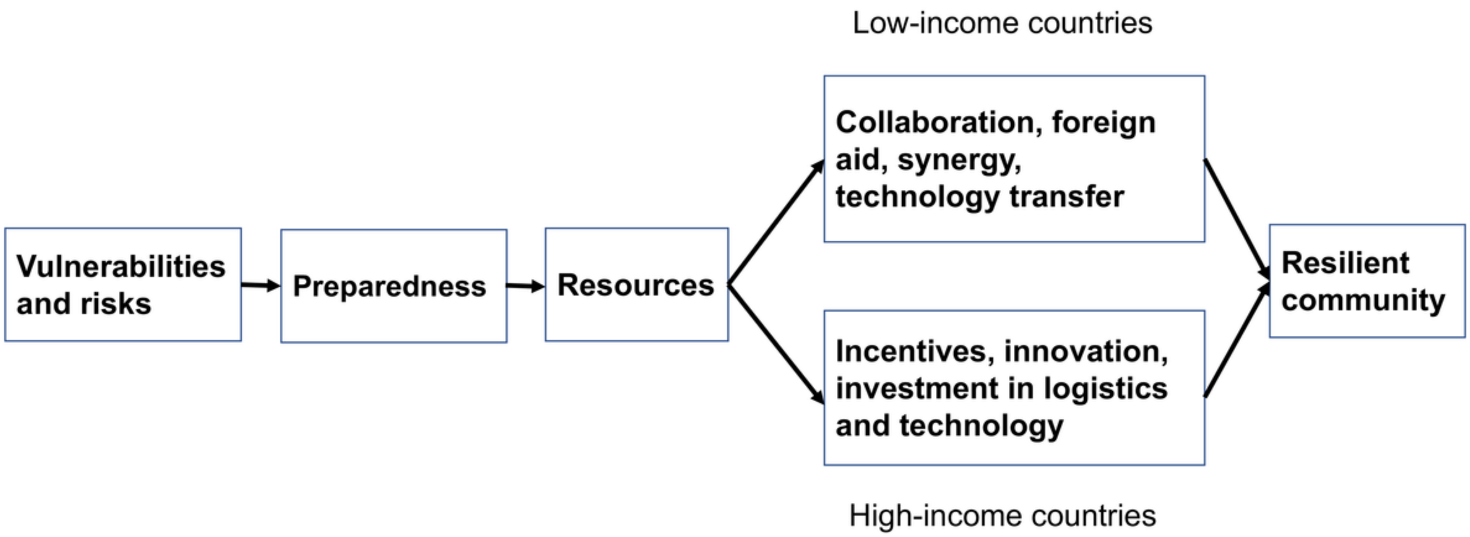

Figure 4

The framework for earthquake preparedness in low- and high-income countries.