SemantJournals

American Journal of Technology Advancement 2997-9382, Vol 03, No. 07, 2026

Article

Legal Framework for Earthquakes Disaster Risk Reduction: A Comparative Review

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Abstract: Effective legal and policy frameworks are essential for reducing earthquake risk and strengthening disaster resilience. This review critically examines the legislative and institutional frameworks governing earthquake disaster risk reduction (DRR), preparedness, and emergency management across selected earthquake-prone countries, with particular attention to building codes, land-use planning regulations, emergency management laws, and international disaster risk governance. A comparative analysis is undertaken of the legal approaches adopted in New Zealand, Chile, Turkey, the United States, and Nigeria to mitigate the seismic vulnerability of existing buildings and communities. The review evaluates these frameworks against the objectives of proactive risk reduction and resilience enhancement embodied in the Sendai Framework for Disaster Risk Reduction 2015–2030. It identifies key strengths, institutional gaps, overlapping mandates, implementation challenges, and examples of effective practices across the selected countries. The findings reveal significant variations in legislative effectiveness, enforcement mechanisms, and institutional coordination, highlighting the importance of integrating risk-informed policies with strong governance and compliance systems. Based on the comparative analysis, the study proposes policy and legal recommendations to strengthen national earthquake disaster management systems, improve regulatory enforcement, and enhance resilience in earthquake-prone regions, particularly in developing countries.

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1. Introduction

The occurrence of an earthquake can neither be prevented nor predicted in precise terms of its magnitude, time of occurrence, and place of its focus. An earthquake is a natural phenomenon, and destructive earthquakes can cause a large number of casualties and property losses. The severity of an earthquake disaster is influenced not only by earthquake parameters but also related to some exposure factors, example building exposure and infrastructure deficit (UNISDR 2009). The seismic disaster risks assessment is an important way to reduce casualties and economic losses[1]. Jiang[2] indicated seismic disaster risk assessment for urban agglomerations in the

Guangdong-Hong Kong-Macao Greater Bay Area, considering four factors: seismic hazard, the volume of seismic hazard exposure (social wealth), vulnerability of the hazard exposure, and the impact of the site[3]. selected 24 indicators from four aspects: hazard intensity, exposure, fragility, and earthquake relief capacity and then performed a refined earthquake disaster risk assessment for 16 districts and counties in the Zhangjiakou area by using expert scoring and the Analytic Hierarchy Process (AHP). Earthquake Disasters are instantaneous and sudden natural calamities. Although the seismic shaking often lasts only tens of seconds, the resulting casualties, particularly in urban and densely populated areas, can be exceptionally severe, surpassing those caused by many other natural hazards such as floods or hurricanes. Most developing countries in Asia, Africa, and Latin America, like India, have a large stock of highly vulnerable housing and community buildings. When impacted by even moderate earthquakes of 5.7 to 6.5 magnitude (Richter scale), large numbers of buildings collapse, leading to loss of lives and loss of limbs and belongings, rendering the people homeless and destitute. Despite contributing to only 8% of total global disasters, one fifth of total direct economic losses, and more deaths than any other natural hazard between 2000 and 2019[4]. Buildings designed with insufficient structural resistance to withstand the force of earthquakes are considered extremely vulnerable to damage and even total structural collapse when subjected to extensive shaking. The 2010 Haiti earthquake caused hundreds of thousands of buildings to collapse and produced a similar number of deaths[5]. The following year, in New Zealand, less than 20 seconds of strong shaking devastated Christchurch, in what was described by then-Prime Minister John Key in "The Sydney Morning Herald"[6]. Solutions have been adopted in New Zealand under the earthquake-prone building framework; the challenge of managing the seismic risk critical insight from international experiences exposes potential gaps in the current framework applied in New Zealand and highlights methods that may be adopted for potential improvement. The ultimate goal should be to build on experiences and enable continued growth, developing legal frameworks that improve the resilience of critical infrastructure. International experience could help improve the earthquake disaster risk reduction strategies; therefore, more needs to be done. Countries are full of earthquakes; to curb their deaths and disastrous nature on infrastructure, the governments have introduced a range of measures aimed at minimizing these catastrophes. These cross-disciplinary global practices are beneficial to knowing how one could enhance the resilience of an earthquake. Countries like Japan and Mexico progress in warming frameworks that designate seismic action at the proper time. The public is advised by such systems in advance, and that is why they can evacuate places quickly with minimal casualties. Nevertheless, in regions susceptible to earthquakes, strategic land-use planning is critical for the reduction of vulnerability. Three countries like New Zealand and the US have seismic considerations in their urban planning governed strictly by building codes controlled mostly by land-use regulations. Intervention of associated policies can enhance the level of resilience. Japan has been successful in reducing the number of people dying during an event, and more importantly, response times have improved due to drill programs on earthquakes coupled with community preparedness plans. With education, training, and coordinated exercises, the communities get humanized, which in turn leads to a culture of preparedness.

2. Materials and Methods

This study adopted a qualitative comparative legal review methodology to examine the legal and institutional frameworks for earthquake disaster risk reduction (DRR) across selected earthquake-prone countries. The review focused on New Zealand, Chile, Turkey, the United States, and Nigeria because these countries represent different levels of seismic risk, legal development, institutional capacity, and disaster management experience. Relevant information was obtained from national legislation, government policy documents, international legal instruments, reports of disaster management agencies, and peer-reviewed academic literature.

International Legal framework, A general overview of the legal frameworks adopted in various countries to achieve disaster risk reduction applies a range of voluntary and mandatory

obligations for addressing the seismic risk of existing structures. These are outlined in the context of the minimum legal standard of seismic risk adopted by each country, with a primary focus on protecting the life safety of building users and the wider general public. The international framework for disaster risk reduction (DRR) is led by the Sendai Framework (2015-2030), supported by the UNFCCC, Paris Agreement, 2030 Agenda for Sustainable Development, and International Health Regulations. Together, these instruments prevent disaster prevention, preparedness, resilience, and international cooperation to reduce disaster risk and strengthen sustainable development[7]. The international legal framework for Disaster Risk Reduction (DRR) is anchored by the Sendai Framework for Disaster Risk Reduction (2015–2030), which provides the primary global roadmap for reducing disaster risks through prevention, preparedness, resilience, and recovery. This framework is complemented by the United Nations Framework Convention on Climate Change (UNFCCC).and the Paris Agreement, which address climate change adaptation and resilience as essential components of disaster risk reduction in 1992. In addition, the 2030 Agenda for Sustainable Development integrates DRR into several Sustainable Development Goals, emphasizing the importance of building resilient communities and reducing disaster-related losses. The International Health Regulations strengthen global preparedness and response to public health emergencies in 2005, while the Convention on Biological Diversity promotes ecosystem-based approaches that reduce disaster risks in 1992. Collectively, these international legal instruments provide a comprehensive framework that fosters international cooperation, sustainable development, and resilience against both natural and human-induced disasters.

National Legal Framework for Disaster Risk Reduction, Nigeria's national legal framework for Disaster Risk Reduction comprises laws, policies, and institutional arrangements that promote disaster prevention, preparedness, response, recovery, and resilience. The National Emergency Management Agency (NEMA) Act of 1999 (as amended) established the National Emergency Management Agency as the lead institution responsible for coordinating disaster management and emergency response across the country[8]. The National Disaster Management Framework (NDMF) provides a coordinated approach to disaster risk management by defining the roles and responsibilities of federal, state, and local governments, as well as other stakeholders[9]. Furthermore, the National Policy on Disaster Risk Reduction 2021 aligns Nigeria's disaster risk management strategies with the Sendai Framework for Disaster Risk Reduction 2015–2030, emphasizing disaster prevention, risk assessment, preparedness, resilience, and sustainable development[10]. In addition, the Climate Change Act 2021 strengthens national efforts to address climate-related disaster risks by promoting climate adaptation and resilience[11]. Similarly, the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act 2007 contributes to disaster risk reduction through environmental protection, pollution control, and the enforcement of environmental standards. Collectively, these legal instruments provide the foundation for disaster risk governance and support Nigeria's commitment to sustainable development and resilience in line with international best practices.

Comparative Review of Earthquake Disaster Risk Reduction , Countries with high seismic activity have developed comprehensive disaster risk reduction (DRR) strategies that integrate legislation, resilient infrastructure, early warning systems, public education, and emergency preparedness. In contrast, countries with low to moderate seismicity, such as Nigeria, are still developing institutional and technical capacities for earthquake risk management. Japan is widely regarded as a global leader in earthquake DRR. The country has established strict seismic building codes, advanced earthquake monitoring and early warning systems, regular nationwide disaster drills, and strong public awareness programs. The Disaster Countermeasures Basic Act and the Japan Meteorological Agency have significantly reduced earthquake-related casualties and economic losses[12]. New Zealand adopts a science-based approach to earthquake risk reduction through stringent building regulations, continuous seismic monitoring by GeoNet, and effective emergency management coordinated by the National Emergency Management Agency (NEMA). Community preparedness and earthquake-resilient infrastructure are central to its DRR

strategy[13]. Chile has one of the world's most effective earthquake resilience systems due to its rigorous seismic building standards, tsunami warning systems, and continuous public education. following the 2010 Maule earthquake, Chile further strengthened its disaster management institutions and emergency response mechanisms[14]. Turkey has significantly improved its earthquake DRR framework through the Disaster and Emergency Management Presidency (AFAD), updated seismic building codes, urban renewal programmes, and enhanced emergency response capacity. However, the 2023 Kahramanmaraş earthquakes exposed challenges related to enforcement of building regulations and urban planning[15]. The United States of America employs a comprehensive earthquake DRR system coordinated by the Federal Emergency Management Agency (FEMA) and the United States Geological Survey (USGS). The country emphasise hazard mapping, seismic monitoring, building code enforcement, earthquake early warning through the ShakeAlert system, and public preparedness campaigns such as the Great ShakeOut[16][17]. In Nigeria, earthquake DRR remains at an emerging stage because the country experiences relatively low seismic activity. Disaster management is coordinated by the National Emergency Management Agency (NEMA), while seismic monitoring is undertaken by the Centre for Geodesy and Geodynamics (CGG).and the Nigerian National Network of Seismographic Stations. Although Nigeria has developed disaster management policies aligned with the Sendai Framework, challenges remain, including limited seismic monitoring infrastructure, inadequate enforcement of building standards, insufficient public awareness, and low investment in earthquake risk assessment. Overall, Japan, New Zealand, Chile, Turkey, and the United States demonstrate that effective earthquake DRR depends on strong legal frameworks, strict building code enforcement, advanced monitoring technology, public education, and sustained investment in disaster preparedness. Nigeria can strengthen its earthquake resilience by expanding seismic monitoring networks, improving compliance with building regulations, enhancing public awareness, and investing in research, early warning systems, and institutional capacity.

Building Codes and Seismic Safety Regulations for Disaster Risk Reduction, Building codes and seismic safety regulations are fundamental components of Disaster Risk Reduction (DRR), as they ensure that buildings and infrastructure are designed, constructed, and maintained to withstand earthquake forces, thereby reducing casualties, property damage, and economic losses. Effective seismic building codes incorporate hazard assessments, engineering standards, quality control during construction, and regular inspections to improve structural resilience. Countries with high seismic risk have established comprehensive seismic design standards. Japan enforces stringent earthquake-resistant building regulations under the Building Standards Act, complemented by regular revisions following major earthquakes and nationwide compliance monitoring. Similarly, New Zealand implements the Building Act 2004 and the New Zealand Building Code, which require earthquake-resistant designs and the assessment and strengthening of earthquake-prone buildings[18]. Chile has one of the world's most rigorous seismic building codes, particularly NCh433, which has contributed significantly to minimizing structural failures during major earthquakes. In the United States, seismic safety is guided by the International Building Code (IBC), ASCE 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures, and the National Earthquake Hazards Reduction Program (NEHRP), all of which promote earthquake-resistant construction and retrofit programs[19]. Turkey has strengthened its seismic safety framework through the Turkish Building Earthquake Code., although recent earthquakes have highlighted the need for stricter enforcement of building regulations. In Nigeria, the National Building Code[20] provides general standards for safe building construction but contains limited provisions specifically addressing earthquake-resistant design because the country has historically been considered a low-seismic-risk region. However, increasing reports of earth tremors have underscored the need to update the building code by incorporating seismic hazard assessments, earthquake-resistant engineering standards, and stronger enforcement mechanisms, particularly in areas vulnerable to seismic activity such as Abuja and parts of north-central Nigeria. Overall, effective building codes and seismic safety regulations are essential for reducing

earthquake risk. Their success depends not only on sound engineering standards but also on strict enforcement, professional compliance, regular updates based on scientific evidence, and public awareness of safe construction practices.

Land-Use Planning and Seismic Hazard Zoning, Land-use planning and seismic hazard zoning are essential components of Disaster Risk Reduction (DRR) because they guide development away from areas highly susceptible to earthquake hazards, including active faults, unstable slopes, liquefaction-prone soils, and landslide zones. Seismic hazard zoning involves identifying and mapping areas according to their level of earthquake risk, enabling governments and planners to make informed decisions on infrastructure development, building design, and emergency preparedness. Countries with high seismic activity have integrated seismic hazard maps into national land-use planning policies. Japan uses detailed seismic hazard maps produced by the Japan Seismic Hazard Information Station (J-SHIS) to regulate urban development, infrastructure siting, and disaster preparedness. Similarly, New Zealand incorporates seismic hazard assessments into regional planning under the Resource Management Act 1991 and the Building Act 2004, ensuring that development in earthquake-prone areas complies with strict engineering and planning standards. Chile and the United States also employ seismic hazard zoning to guide urban planning and infrastructure development. In the United States, the United States Geological Survey (USGS) develops national seismic hazard maps that support building codes, land-use planning, and emergency management[21]. Turkey has expanded seismic microzonation studies and urban transformation programs.to reduce earthquake risks in vulnerable cities following recent major earthquakes. In Nigeria, land-use planning has traditionally focused on flood, erosion, and environmental hazards, with limited integration of seismic hazard assessments because of the country's relatively low seismicity. However, recurring earth tremors in Abuja, Mpape, Kwoi, and other parts of north-central Nigeria highlight the need to incorporate seismic hazard zoning into urban planning, infrastructure development, and building approval processes. Strengthening geological investigations, geospatial mapping, and seismic hazard assessments will improve disaster preparedness and reduce future earthquake risks[22]. Effective land-use planning and seismic hazard zoning reduce exposure to earthquake hazards, support resilient infrastructure development, and enhance sustainable urban growth. Integrating hazard maps into planning policies, enforcing zoning regulations, and adopting risk-informed development are essential for minimizing earthquake-related losses.

Enforcement Challenges, The effectiveness of Disaster Risk Reduction (DRR) measures depends not only on the existence of laws and policies but also on their consistent enforcement. Many countries, particularly developing nations, face significant challenges in implementing building codes, land-use regulations, and seismic safety standards due to weak institutional capacity, inadequate funding, corruption, and poor regulatory oversight. A major challenge is the weak enforcement of building codes, which often results in the construction of substandard structures that are highly vulnerable to earthquake damage. In countries such as Turkey, investigations following the 2023 Kahramanmaraş earthquakes revealed that poor compliance with seismic regulations and inadequate inspection contributed to widespread building failures. Similarly, inadequate monitoring and enforcement remain concerns in many developing countries. Another challenge is rapid urbanization and informal settlements, where buildings are frequently constructed without proper planning approval or adherence to engineering standards. Limited technical expertise, insufficient numbers of trained inspectors, and inadequate public awareness further hinder compliance with disaster risk reduction regulations. In Nigeria, enforcement challenges include weak implementation of the National Building Code, inadequate institutional coordination, limited seismic hazard data, insufficient funding, and poor compliance with planning regulations. The absence of mandatory earthquake-resistant design standards in many parts of the country also limits preparedness for future seismic events. Addressing these challenges requires stronger institutional capacity, regular building inspections, effective enforcement of planning regulations, improved professional accountability, increased investment in disaster risk

management, and greater public awareness of the importance of compliance with building and land-use regulations.

3. Results and Discussion

The comparative review demonstrates that countries with high seismic activity have developed significantly more comprehensive legal and institutional frameworks for earthquake disaster risk reduction than countries with low to moderate seismic exposure. Japan, New Zealand, Chile, Turkey, and the United States have integrated seismic risk considerations into building regulations, land-use planning, emergency preparedness, and public awareness programmes, whereas Nigeria's legal framework remains relatively underdeveloped in relation to earthquake-specific risk management.

The findings further indicate that the effectiveness of earthquake disaster risk reduction is determined not only by the existence of legal provisions but also by the strength of institutional implementation and regulatory compliance. Countries such as Japan and New Zealand have demonstrated that periodic revision of seismic regulations, coupled with rigorous inspection mechanisms and accountability systems, significantly enhances the resilience of both public and private infrastructure. Conversely, where enforcement mechanisms are weak or inconsistent, the existence of comprehensive legislation alone is insufficient to reduce disaster risks effectively.

Another important observation from the comparative analysis is the growing role of science and technology in supporting legal and policy frameworks for disaster risk reduction. Advanced seismic monitoring networks, geospatial hazard mapping, satellite-based observations, and earthquake early warning systems have become integral components of disaster governance in developed countries. The integration of these technologies into legal and institutional arrangements enables governments to make evidence-based decisions, improve emergency preparedness, and reduce response times during seismic events. Countries with limited technological infrastructure may therefore benefit from increased investment in geospatial information systems and real-time monitoring technologies.

The review also reveals that successful disaster risk reduction depends on effective collaboration among multiple stakeholders, including government agencies, scientific institutions, local authorities, engineering professionals, and the public. Countries with well-coordinated governance structures have achieved greater consistency in implementing building standards, conducting public awareness campaigns, and organizing emergency preparedness exercises. Such multi-sectoral coordination strengthens institutional resilience and facilitates efficient disaster response and post-disaster recovery.

4. Conclusion and Recommendations

This paper has addressed the conventional and domestic legal rules applicable to disaster management in some vulnerable countries mentioned as examples. The legal framework for disaster risk reduction (DRR) encompasses national and international laws, policies, and regulations designed to prevent new risks, reduce existing ones, and manage residual risks. It requires risk assessments, land-use planning, early warning systems, and clear institutional responsibilities across all levels of government. Parliamentarians in various states are discussing the option of a model law for the region to be used across the region. In Nigeria, notable initiatives have been undertaken to strengthen Nigeria's emergency management system, including the inclusion of risk reduction in university curricula; unfortunately, ongoing progress has been accompanied by corresponding obstacles such as poverty and lack of collaboration among levels of government. While public officials may be cognizant of gaps and weaknesses within legal and policy frameworks, this awareness should be followed up with concrete actions to strengthen those frameworks and to implement needed solutions to new and existing challenges through

legislation. It is hoped that this report will provide clear guidelines to governments and policymakers to enable them to bring their legal and institutional frameworks in alignment with international standards such as the Sendai Framework, as well as support public authorities with a pathway for achieving their Sustainable Development Goals. To strengthen earthquake disaster risk reduction (DRR), governments should update and enforce seismic building codes based on current scientific and engineering standards to improve the resilience of buildings and critical infrastructure. Land-use planning should incorporate seismic hazard maps to prevent development in high-risk areas and guide sustainable urban growth. Governments should also expand seismic monitoring networks, invest in earthquake early warning systems, and strengthen disaster preparedness through regular emergency drills. Awareness campaigns, Institutional coordination among disaster management agencies, planning authorities, and research institutions should improve in disaster governance and emergency response. For Nigeria, priority should be given to revising the National Building Code to include comprehensive earthquake- resistant design, and strengthening enforcement of planning regulations. Nigerian National Network of Seismographic Stations, should upscale investment in seismic hazard mapping, geoscientific research, and professional training. These measures will improve national preparedness and reduce vulnerability to future earthquake events.

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