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Earthquake Risk in Bangladesh: Lesson Learned from Turkiye-Morocco Earthquake

Maliha Haque[1,*], Mumtahina Akter [1], M. Shahidul Islam [1]

[1] Department of Geography and Environment, University of Dhaka, Dhaka-1000, Bangladesh

*Correspondence: haque.maliha@du.ac.bd

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Abstract: Turkey, Morocco, and Bangladesh are all located in active seismic zones of the Earth's surface. Recent studies have predicted catastrophic earthquakes in Bangladesh in the near future. Since disasters can act as catalysts for learning by exposing the shortcomings and vulnerabilities of communities or governments, it is believed that Bangladesh has much to learn from the 2023 mega-disasters in Turkey and Morocco. Therefore, this study aims to understand the causes of the catastrophic earthquakes in Turkey and Morocco. The main objective is to analyze the strengths and weaknesses of the disaster management stages during the 2023 earthquakes in Turkey and Morocco, and to compare these with the situation in Bangladesh to better understand potential earthquake risks there. Moreover, the study seeks to develop a framework for Disaster Learning. It follows a qualitative research methodology, with most of the necessary data gathered from existing literature and Key Informant Interviews. The findings suggest that infrastructural vulnerabilities and noncompliance with land use regulations were significant causes of the catastrophic damage in Turkey and Morocco, which are also relevant to the earthquake risks in Bangladesh. Key strengths identified in Turkey include the availability of open spaces for emergency services, wide roads, modern equipment, skilled manpower, military-civilian coordination, and a robust humanitarian response—all areas where Bangladesh has significant deficiencies. Lessons from this study reveal that climatic conditions and debris management could pose major challenges for Bangladesh in the event of a significant earthquake.

Keyword: Lesson; Earthquake; Bangladesh; Turkiye; Morocco

1.0 Introduction

Turkey, Morocco, and Bangladesh—all three countries lie in seismically active regions of the Earth's surface. Turkey is situated over the Anatolian Plate, with the faults along the eastern and northern boundaries, known as the Eastern Anatolian Fault (EAF) and Northern Anatolian Fault (NAF), being primarily responsible for the country's historic earthquakes (Erdik, 2013; Gencer, 2013). In Morocco, the entire Mediterranean belt is seismically active due to its location in the subduction zone of the Eurasian Plate and the African Plate; thus, the Haouz High Atlas area near Marrakech is particularly vulnerable to earthquake disasters (Khalloufi et al., 2023). Although Bangladesh lies thousands of miles away from Turkey and Morocco, it shares similar earthquake vulnerabilities, as it is located at the boundary of the Indo-Eurasian and Indo-Burmese Plates. These plates gradually move and create potential strains for earthquakes (Sella et al., 2002; Bilham, 2009). Studies have indicated a high likelihood of a major earthquake occurring in Bangladesh in the near future (Islam et al., 2016; Morino et al., 2013).

The year 2023 has been marked by devastating earthquakes that highlighted the severity of seismic disasters in Turkey, Syria, Morocco, Afghanistan, the Philippines, Nepal, and China. Bangladesh also recorded six earthquakes in 2023 with magnitudes above 5.0 (Bangladesh records, 2023). Disasters not only cause significant damage and loss to the economy, society, and environment, but they also serve as indicators of existing vulnerabilities and inadequate preparedness in affected areas. Holistically, disasters can act as teaching opportunities, allowing us to analyze the effectiveness of local or national disaster contingency plans. They reveal the limitations and vulnerabilities of communities or administrations and create avenues for improving weaknesses and strengthening preparedness plans. Therefore, disasters should also be viewed as valuable learning experiences.

Since Turkey, Morocco, and Bangladesh share similar seismic and social vulnerabilities (Letsch, 2023; Bilginsoy and Fraser, 2023; Osman, 2023; The World Bank, 2013), the researchers of the current study believe that a comparative analysis of the 2023 Turkey-Morocco earthquakes with Bangladesh will serve as a valuable learning guide for Bangladesh. Therefore, this research seeks to explore the causes behind the disastrous impacts of the 2023 earthquakes in Turkey and Morocco and aims to identify weaknesses in their preparedness as well as their strengths in disaster management. The ultimate goal of the researchers is to conduct a comparative study between Turkey, Morocco, and Bangladesh, and to highlight the lessons learned from the Turkey-Morocco earthquakes to help reduce earthquake risks in Bangladesh. Moreover, the study aims to develop a framework for Disaster Learning.

Moreover, previous studies on earthquake risks in Bangladesh have primarily focused on seismic vulnerability, land use, or infrastructural weaknesses (Alam and Howes, 2016; Islam et al., 2016; Morino et al., 2013; Rahman, 2023; Senjuti and Islam, 2014). However, this study, in addition to those, examines risks in Bangladesh related to emergency response, manpower, equipment, and humanitarian efforts, drawing insights from the experiences of Turkey and Morocco.

2.0 Study Area

This research aims to identify the earthquake risks, weaknesses, and vulnerabilities in Bangladesh based on lessons learned from the earthquake-affected areas of Turkey and Morocco. However, the study focuses exclusively on Dhaka city. Dhaka, the capital of Bangladesh, is situated between longitudes 90°20″ E and 90°30″ E, and latitudes 23°40″ N and 23°55″ N. It is one of the most densely populated megacities in the world, covering an area of 306.4 km^2 (Rahman, 2022). The city features a complex and mixed land setting in the central part of Bangladesh, encompassing both the Madhupur Tract (an alluvial terrace from the Pleistocene period) and the Brahmaputra-Jamuna floodplain (Karim et al., 2019). Topographically, the area is flat, with surface elevations ranging between 1 and 14 m; most built-up areas are located at elevations of 6–8 m (Ishtiaque et al., 2014). In 2021, the land use composition in this area was as follows: Built-Up Area (66%), Vegetation Land (6%), Water Body (5%), and Bare Soil (23%) (Rahman, 2022).

Kahramanmaras Province in Turkey is primarily a mountainous region, comprising 59.7% mountains, 24% plateaus, and 16.3% plains. It covers an area of 14,468 km², making it the 18th largest province in Turkey (Esen and Avci, 2018). Approximately 34.63% of the province is agricultural land, while other dominant land uses include shrub and pasture (Ekren, 2022). Adana and Gaziantep are neighboring provinces affected by the earthquake and are among the most populated cities in Turkey (World Population Review, 2024). The 2023 Morocco earthquake

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struck the western central region of the country, specifically in the High Atlas Mountains. The affected area is predominantly rural and mountainous.

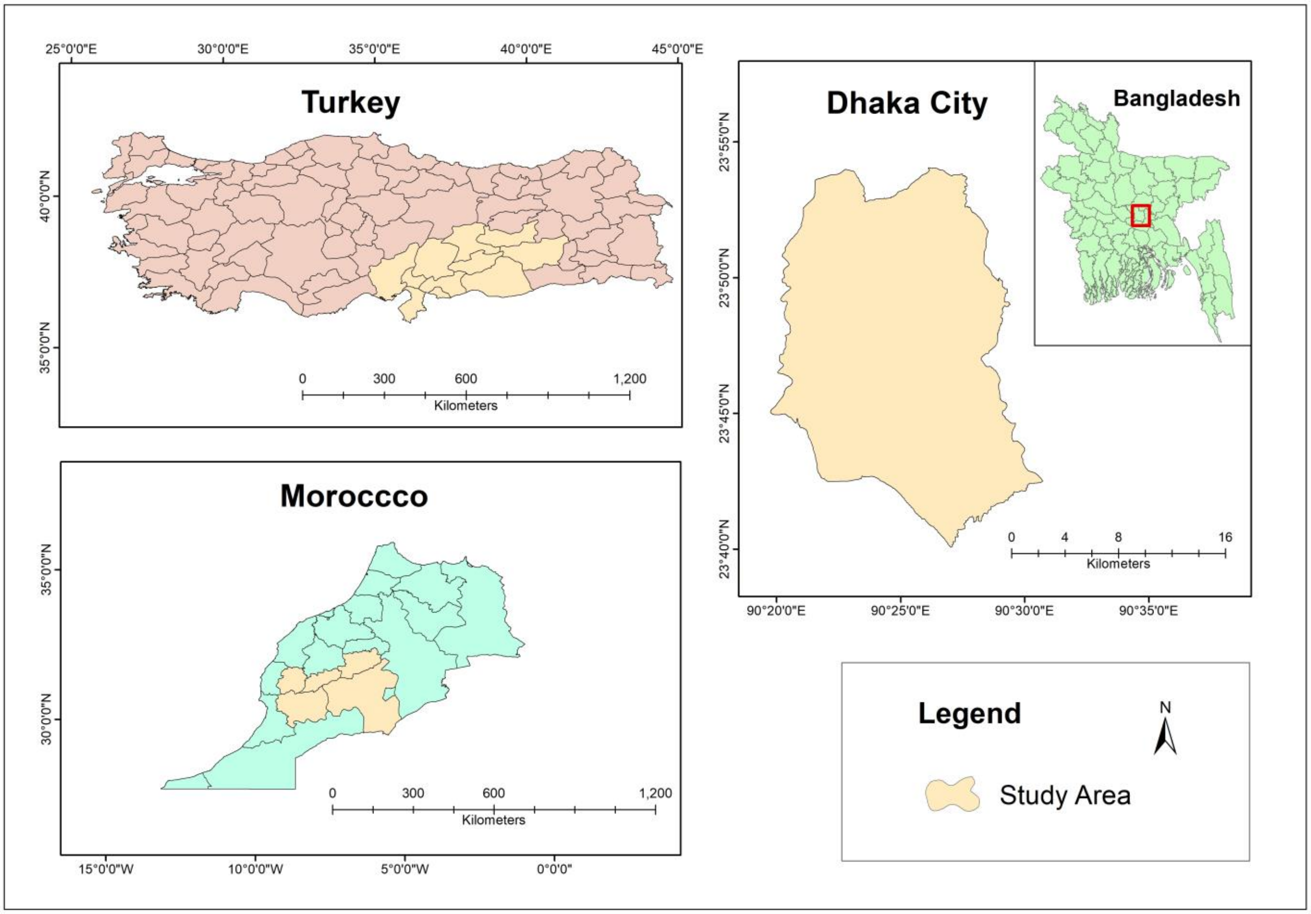

Figure 1: Study areas of the research.

3.0 Materials and Methodology

The principal objective of this research is to analyze and document the lessons learned from the Turkey-Morocco earthquake, ultimately producing a set of recommendations to help Bangladesh (with a special focus on Dhaka City) mitigate the risks of similar catastrophic earthquake damage. To achieve this, the paper aims to identify the underlying causes of the significant destruction in Turkey and Morocco and to compare vulnerabilities, weaknesses, strengths, preparedness, emergency response, and humanitarian assistance between Turkey, Morocco, and Bangladesh. Simultaneously, the research will attempt to develop a 'Framework for Learning Lessons from Disasters' to facilitate further comparative studies. To reach these objectives, the study adopted a qualitative research methodology. A detailed analysis of Turkey and Morocco was supported by a literature review of existing journals, books, situation reports, and newspaper articles. Additionally, direct interviews with members of the Bangladesh Fire Service and Civil Defence (BFSCD) who worked in Turkey provided valuable insights for understanding and analysis.

4.0 Results

4.1 Seismic Vulnerability of Turkiye and Morocco

Turkey's location on the Anatolian Plate, surrounded by the Eurasian Plate to the north, the Arabian Plate to the east, and the African Plate to the southwest, makes it one of the most active seismic regions on Earth. The westward-moving Anatolian block creates a strike-slip fault with the southeastward-moving Eurasian Plate, and the North Anatolian Fault line is responsible for many of Turkey's severe historic earthquakes, notably the 1939 and 1999 earthquakes (Erdik, 2013; Gencer, 2013). To the east of Turkey lies the East Anatolian Fault, a left-lateral strike-slip fault formed by the northeast-moving Arabian Continental Plate along the edge of the Anatolian Plate. This fault zone accumulates a tectonic slip deficit at a rate of approximately 10 mm per year, with the resulting strain released by periodic earthquakes of magnitude 7 or above (Zilio and Ampuero, 2023). The transform plate boundaries along northern and eastern Turkey, combined with the subduction zone to the south, contribute to Turkey's high seismic vulnerability and frequency of earthquakes. Paleo-seismological studies indicate that the average recurrence period of large, devastating surface-rupturing earthquakes along the North Anatolian Fault is approximately 350 years (Pucci et al., 2009), while the mean recurrence interval for the East Anatolian Fault is around 190 years, based on data over 3,800 years (Ferrari et al., 2020). Guvercin et al. (2022) identified varying recurrence intervals for different segments of the East Anatolian Fault, ranging from nearly 150 years with maximum magnitudes of 6.7–7.0 in the most active eastern zone to 414–917 years in the western silent

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zone, indicating potential for extreme events. The last earthquake along this fault with a magnitude above 7.0 occurred in 1893, while a significant earthquake of magnitude 6.8 struck in 1905. Consequently, a long period of seismic silence has developed along this fault line (Ambraseys and Jackson, 1998; Nalbant et al., 2002; Cetin et al., 2003).

On the other hand, the subduction zone created by the convergence of the Eurasian Plate and the African Plate, which led to the formation of the Atlas Mountains, poses a major seismic threat to Morocco. The entire Mediterranean belt is seismically active due to the convergence of these two plates at a rate of 4–10 mm/year. The eastern part of the Mediterranean belt is particularly seismically active, while the High Atlas Mountain segment is moderately active (USGS, 2023d; Sebrier et al., 2006). The recurrence rate of severe earthquakes in individual faults within the Moroccan region is approximately once every thousand years, while low to moderate magnitude earthquakes are more common (GFZ, 2023).

4.2 Turkiye and Morocco Earthquake 2023

In February 2023, Turkey was hit by two major earthquakes. The first had a magnitude of 7.8, with its epicenter located south of Kahramanmaras Province. This was followed by a second earthquake of magnitude 7.5 to the east of Kahramanmaras. The time lag between the two earthquakes was 9 hours. Both events had shallow centers, occurring only 10 km below the surface. These earthquakes affected the southern part of Turkey as well as northern Syria and originated along the long-dormant East Anatolian Fault (EAF) (USGS, 2023a). In September 2023, a 6.8 magnitude earthquake occurred at a depth of 26 km below the surface, with its epicenter in Al Haouz, Morocco. This earthquake was also followed by minor aftershocks. The subduction zone beneath the High Atlas Mountains was the cause of the tremors (USGS, 2023d).

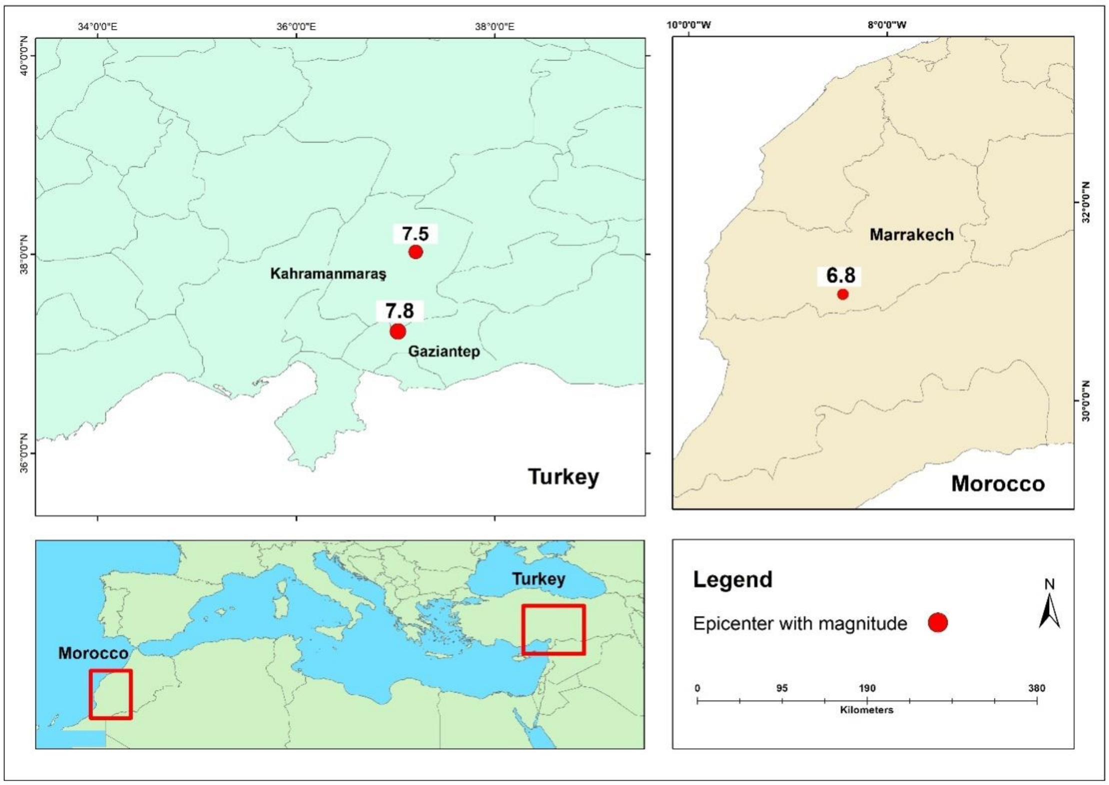

Figure 2: Epicenters of the Turkey and Morocco Earthquakes with Magnitude (USGS, 2023a; USGS, 2023b; USGS, 2023d).

4.3 Consequences of Turkiye and Morocco Earthquake

According to the Disaster and Emergency Management Authority (AFAD), the paired earthquakes in Turkey caused the deaths of more than 50,000 people and left another 107,204 injured ("Turkey's earthquake death toll," 2023). More than 160,000 buildings collapsed, resulting in approximately 116–220 million tons of debris (Toksabay and Butler, 2023). The earthquakes affected 11 provinces in southern Turkey, causing damages estimated at 84.1 billion USD, with an additional 70.8 billion USD required to reconstruct the infrastructure, according to a report by the Turkish Enterprise and Business Confederation (Devranoglu, 2023). The World Bank (2023) estimates that rehabilitation and reconstruction will cost more than the actual damage. The World Bank's Rapid Damage Assessment Report indicated that the earthquakes have caused financial losses equivalent to almost 4% of the country's GDP. The affected provinces account for 14% of Turkey's fisheries production and 11% of the country's total GDP, both significantly impacted by the disaster (Lawati, 2023). Disruptions in utility services, educational institutions, religious institutions, and health services have serious short- to medium-term impacts, including internal migration, changes in the demographic pyramid, and educational gaps. Moreover, the geopolitical impacts of the earthquake were profound, as this area is home to 50% of Syrian refugees (UNHCR, 2022) who lost their means of rehabilitation due to the earthquakes. The return of many Syrian refugees to their homeland (Azhari, 2023), the potential loss of control over northern Syria, internal political turbulence, the declining popularity of President Erdogan prior to elections, and the possible threat to the strong position of Islam in Turkey were some of the major political impacts of the earthquakes. Additionally, environmental impacts such as the creation of rupture lines, liquefaction, and land subsidence were observed

(Ravilious, 2023; Scarr et al., 2023). The situation in Morocco is similarly dire. Nearly 3,000 people lost their lives, and more than 5,500 were injured due to the earthquake, which caused the displacement of around 500,000 individuals. More than 60,000 buildings were damaged, one-third of which were completely destroyed (Morocco Earthquake: Situation Report #4, 2023; Lawder, 2023). An estimate from the USGS confirms that the earthquake could cause financial losses of up to 8% of the country's GDP (Helou, 2023). In addition to the disruption of utility services and building collapses, nearly 530 educational institutions were damaged, severely affecting educational continuity (Farag, 2023). Like Turkey, Morocco's tourism sector has also been impacted due to damage to tourist sites, including the UNESCO World Heritage Site Medina, Koutoubia Mosque, and the Atlas Mountains (Turner, 2023; Elshamy & Metz, 2023).

4.4 Probing into Causes of Massive Damage in Turkiye-Morocco Earthquake

In both Turkey and Morocco, traditional building construction techniques, violations of building codes, and weak law enforcement have emerged as major causes of widespread destruction. Turkey developed and updated the 'Turkish Earthquake Code' (TEC) in 1940, 1944, 1947, 1953, 1961, 1968, 1975, 1998, 2007, and 2018. Despite these updates, approximately 50% of Turkey's buildings do not comply with the latest building codes, according to estimates (Letsch, 2023). The building codes established before 1998 lacked adequate capacity design and ductility concepts (Ozturk et al., 2023). The TEC 1998 was somewhat more effective, and buildings constructed after its implementation were relatively safer, but those designed after the TEC 2018 are considered the safest (Ibid).

Multi-storied concrete buildings without reinforced concrete (RC) bars are often unable to withstand the lateral stresses of an earthquake. Steel bars have a better capacity to endure shear forces, which are complemented by concrete to create reinforced concrete (RC). To construct earthquake-resilient buildings, it is essential to use RC bars, maintain proper proportions in the concrete mix, and ensure appropriate spacing of beams and columns, employ base isolation techniques, and reinforce weak masonry walls (Ahmed, 2023). Unfortunately, these practices were often lacking in Turkey's traditional buildings (Horton & Armstrong, 2023; Beaumont, 2023). Major reasons for mass building collapses include limitations in building codes, construction on weak soil, liquefaction effects, shaking intensity, the use of traditional ribbed slabs, soft stories, brittle columns, and insufficient strengthening applications (Ozturk et al., 2023; Wang et al., 2023).

In 2022, the Environment and Urbanization Minister of Turkey pledged to ensure that every building in Turkey would be 'earthquake safe' by 2035. Initiatives for retrofitting were introduced, accompanied by financial incentives. However, the absence of legal binding in urban transformation projects, along with corruption and unethical practices among contractors, led to the failure of these retrofitting efforts (Bora, 2023). Older buildings constructed before the standardization of construction rules have undoubtedly suffered severely. Even recently constructed buildings that were touted as earthquake-resistant failed to withstand seismic activity. This indicates that violations of regulations and corruption are widespread (Bilginsoy and Fraser, 2023).

Similarly, in Morocco, houses are traditionally built with mud bricks and lack reinforcement. When these structures collapse, they quickly turn into earthen rubble, which complicates rescue operations (Andrews, 2023; Eljechtimi and Pereira, 2023). It is claimed that the government encouraged the use of mud-brick buildings to enhance the aesthetic appeal of tourist areas (Osman, 2023).

Research suggests that the people in the affected areas of Turkey had limited knowledge of earthquake preparedness (Uludag, 2023). According to the study by Oral et al. (2015), individuals in Turkey who had previously experienced disaster losses were more likely to take precautions than those who had not. In 2009, Turkey established the National Disaster and Emergency Management Authority (AFAD), and in 2014 developed a national Disaster Response Plan. However, the plan was never fully implemented, and as a result, AFAD's mission to strengthen local community capacity, regularly monitor risks, and train personnel was only partially achieved (Comfort et al., 2023).

A significant portion of the blame for the failure can also be attributed to the shortcomings in Turkey's emergency response. A rigid planning process, poor coordination, and an initially politically charged response were identified as major causes of the delay. Additional factors, such as a lack of awareness and training programs in the affected areas, failure to deploy the military promptly, limited civilian participation, authoritarian governance, and a highly centralized power structure, greatly amplified the damage (Yildiz, 2023).

4.5 Humanitarian Help

Turkey received substantial support from both allies and adversaries alike. Several international organizations extended financial and humanitarian aid in response to the catastrophic disaster. Muslim nations in particular demonstrated solidarity by assisting Turkey, highlighting Muslim unity. The World Bank announced $1.78 billion in aid for relief and reconstruction efforts (The World Bank, 2023). Around eighty countries, including Bangladesh, reportedly sent supplies, equipment, rescue personnel, and other forms of aid to Turkey. NATO deployed more than 1,400 soldiers from 20 different nations to assist (Wilson, 2023). Similarly, nations such as the UK, UAE, Qatar, and Spain provided rescuers and financial aid to support Morocco during its earthquake crisis ("Foreign rescuers join," 2023). The European Union contributed an initial €1 million in humanitarian aid to help those in the hardest-hit areas (European Commission, 2023).

4.6 Earthquake Vulnerability and Risks in Bangladesh

Bangladesh's location in the northeastern corner of India, bounded by the Indo-Eurasian plate boundary to the north and the Indo-Burmese plate boundary to the east, makes it seismically active and tectonically vulnerable to earthquakes. The Indian plate moves northeastward at a rate of 6 cm per year, subducting under the Eurasian plate at 45 mm per year and the Burmese plate at 35 mm per year, generating significant strain that could trigger earthquakes (Sella et al., 2002; Bilham, 2009). In addition to the plate boundaries, several regional fault lines—including the Dauki fault along the southern edge of the Shillong plateau, Madhupur fault, Sylhet-Assam fault line, and the Tripura and Arakan segments of the mega-thrust—pose significant earthquake potential (Morino et al., 2014; Islam et al., 2023). Historically, Bangladesh has experienced several large earthquakes in 1548, 1642, 1663, 1762, 1775, 1812, 1865, 1869, 1885, 1897, 1918, 1923, 1930, 1934, 1950, 1954, 1977, 1997, 1999, 2003, 2006, 2008, 2009, 2010, and 2011, with some reaching magnitudes of up to 8.7 (Alam and Howes, 2016; Islam et al., 2016). The average recurrence period of the Dauki fault is 350-700 years (Morino et al., 2014), with the most recent event occurring in 1897 (Oldham, 1899), indicating a 126-year gap. The Madhupur fault, an intra-plate active fault, has a longer recurrence period of several thousand years, with the last major event occurring in 1885 (Tahsin et al., 2018). However, the Tripura and Arakan segments of the mega-thrust now present significant threats to the country. The Tripura segment has a recurrence interval of 2,000 years, with the last event estimated between 1120 and 400 BC, while the Arakan segment has a 300-450 year interval, with the last major earthquake occurring in 1762 (Morino et al., 2013). Given the accumulation of tectonic energy in the eastern part of Bangladesh, cities like Dhaka, Chattogram, and Sylhet are at high risk of earthquakes. This risk is acknowledged in the Bangladesh National Building Code (BNBC) 2021, which revised the seismic zoning map of Bangladesh, as shown in Figure 3. These threats are no longer mere estimations, as Bangladesh experienced several earthquakes in 2023 with epicenters both within and adjacent to the country, as shown in Figure 4.

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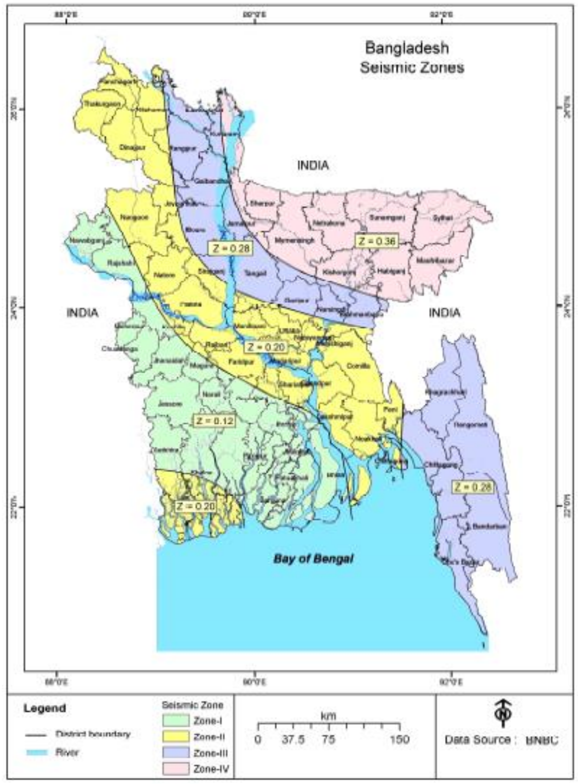

Figure 3: Revised seismic zone of Bangladesh (BNBC, 2021).

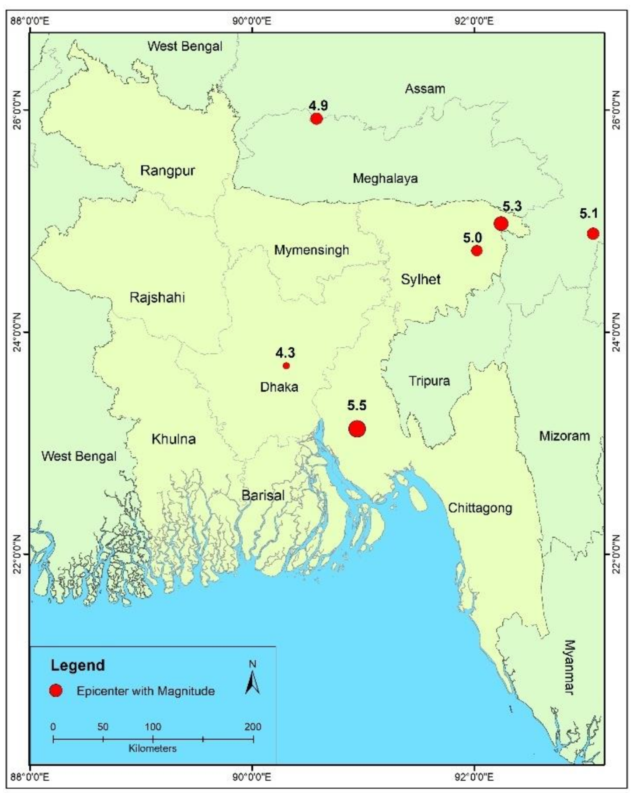

Figure 4: In 2023, Bangladesh experienced a series of notable earthquakes, with multiple epicenters located within the country. Notably, three of these earthquakes registered magnitudes higher than 5 on the Richter scale (USGS, 2023c).

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Physical vulnerability, combined with socio-demographic and economic factors, places Bangladesh among the world's most earthquake-vulnerable countries (The World Bank, 2013). According to the 2022 census, 10,278,882 people currently reside in Dhaka, with a population density exceeding 34,000 people per square kilometer (BBS, 2022). In addition to rapid population growth, the city has seen a sharp increase in building construction. As per RAJUK, approximately 100,000 new buildings are constructed annually in Dhaka (Karim, 2022). To support the analysis, this research conducted satellite image analysis using the Normalized Difference Built-up Index (NDBI), which identified an increase in built-up areas, as shown in Figure 5.

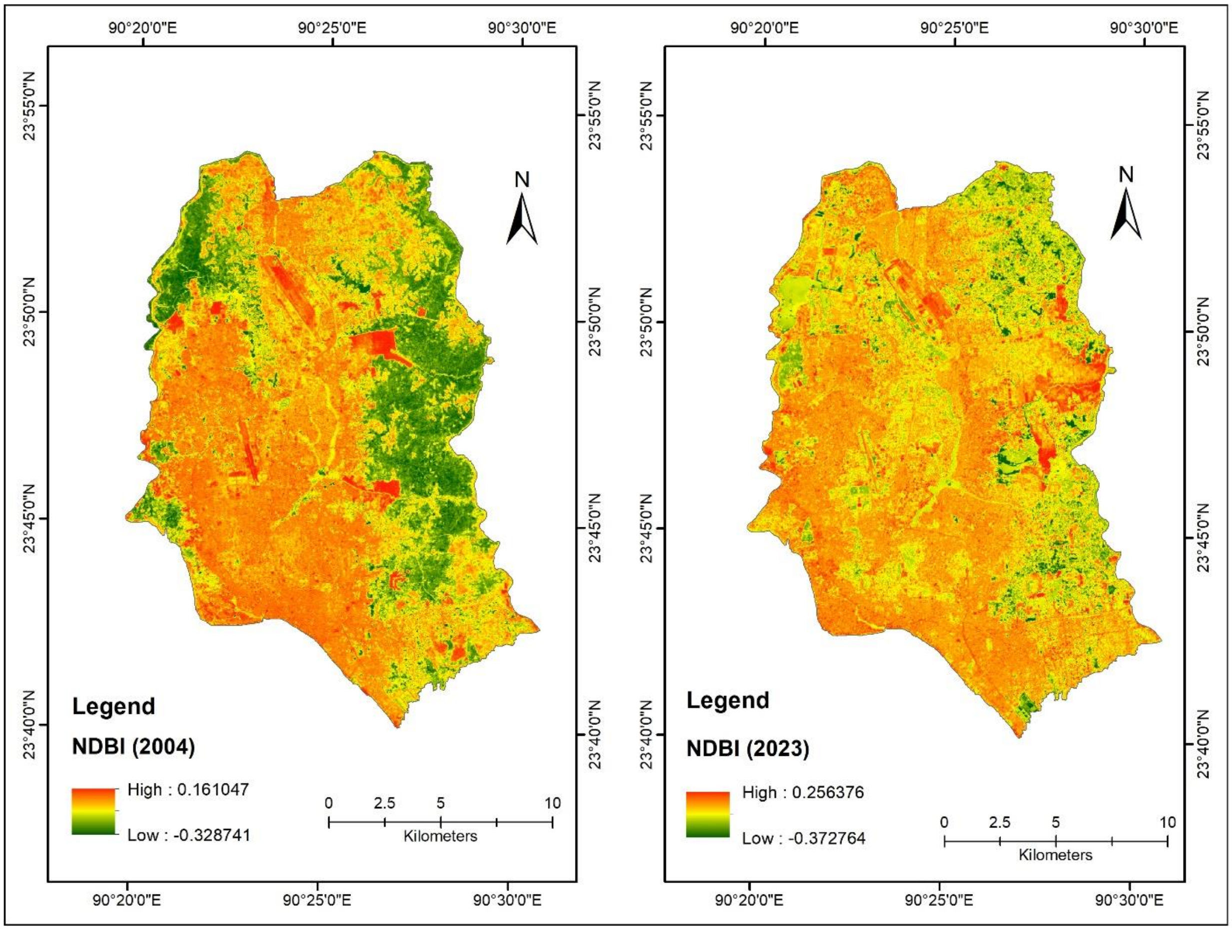

Figure 5: Normalized Difference Built-Up Index (NDBI) of Dhaka City over a 20-Year period, clearly indicating an increase in built-up areas, particularly in the Peripheral Regions of Dhaka.

However, it is astonishing that out of 2.146 million establishments, only 85,000 have a proper design layout (Ibid). Bolt (1987) estimated that the maximum potential earthquake magnitudes for the Assam Fault, Tripura Fault, Sub-Dauki Fault, and Bogra Fault are 8.0, 7.0, 7.3, and 7.0, respectively. This raises questions about whether establishments that violate design and safety standards can withstand such critical seismic risks. A study by Senjuti and Islam (2014) on 9,839 buildings in Uttara revealed that a minimum of 6,214 buildings in the area would be partially or fully damaged in the event of a 7.2 magnitude earthquake, potentially killing 16,788 people and injuring 100,823. A RAJUK survey found that approximately 900,000 buildings are at risk of collapse (Rahman, 2023). The CDMP report (2009) estimated that over 50% of some areas in Dhaka city could be fully damaged and irrecoverable. Additionally, the report highlights often overlooked disaster impacts, such as the reduced functionality or shrinking service capacity of utility and emergency health services after each passing day and the accumulation of approximately 18-30 million tons of debris. However, building design alone is insufficient to build resilience. Land use planning and compliance with zoning regulations are of utmost importance. In Dhaka city, 67% of commercial and 51% of industrial buildings have violated DAP zoning restrictions, and a significant percentage of infrastructure has been built in vulnerable areas, such as flood-prone zones or designated open spaces (Rahman et al., 2021). Liquefaction poses a serious threat to unconsolidated soil. In the event of a magnitude 7 earthquake, parts of Shyampur, Badda, Demra, Sabujbag, Pallabi, and Mirpur could experience up to 72% liquefaction due to alluvium and artificial landfill soil (Rahman et al., 2015).

Research has shown that in Bangladesh, even professionals often lack knowledge about compliance, enforcement, and capacity. The absence of widespread awareness and the increase in informal buildings are significant weaknesses. In developing countries like Bangladesh, complying with building codes is often perceived as 'expensive,' leading to high rates of violations due to economic vulnerability (Ahmed et al., 2019). Financial constraints and corruption are major drivers behind the failure of mass retrofitting efforts in Dhaka. Additionally, narrow roads and the decreasing amount of open space around the city pose significant challenges to effective emergency response and increase risks.

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According to information from the Ministry of Disaster Management and Relief, the Government of Bangladesh has procured equipment for search and rescue operations, as well as emergency communication for earthquakes and other disasters. This equipment will be distributed among ten institutions, including the Fire Service and Civil Defense, the Armed Forces, Bangladesh Navy, Coast Guard, Cyclone Preparedness Program (CPP), Bangladesh Red Crescent Society, Bangladesh Police, Rapid Action Battalion (RAB), and Border Guard Bangladesh. Ten warehouses have been constructed in Demra, Khilgaon, Sadarghat, Hazaribagh, Kalyanpur, Postogola, Uttara, Savar, and Tongi. An Emergency Operation Center (EOC) has been established in Mirpur, Dhaka, with another EOC in Sylhet. The government has also made progress at the policy formulation level, including the creation of the National Dead Body Management Guideline, the Draft Debris Management Plan for Dhaka, Chittagong, and Sylhet, and the National Debris Management Guideline (Draft). Risk assessments have been conducted in the three most vulnerable cities of Bangladesh: Dhaka, Chattogram, and Sylhet. The National Earthquake Contingency Plan has been developed, outlining potential threats and risk scenarios, standard operating procedures, emergency response tasks for functional groups in preparedness and mitigation phases, capacity and awareness-building procedures, and the establishment of a National Emergency Operation Center (NEOC) with a reporting system.

In addition to the national contingency plan, district and ward-level earthquake contingency plans have also been developed in line with the national plan. The Bangladesh National Building Code was revised in 2020. To identify areas for increased preparation and risk mitigation, as well as to establish multilateral cooperation for disaster response between Bangladesh and the United States, the Disaster Response Exercise and Exchange (DREE) has been developed. This initiative is part of the Pacific Resilience of USARPAC's Humanitarian Assistance and Disaster Relief Initiative since 2010, with Bangladesh actively participating in DREE exercises held every year. In addition to policy, regulation, and guideline formulation, Bangladesh is working on capacity building for its personnel. Between 2005 and 2020, 68 members from the BFSCD successfully completed international training on Urban Search and Rescue (USAR) in various countries, including Australia, China, India, Malaysia, Nepal, the Philippines (INSARAG), Singapore, South Korea, and the USA. Bangladesh has also actively participated in regional training programs such as the Program for Enhancement of Emergency Response (PEER), supported by USAID's Office of U.S. Foreign Disaster Assistance, and the Collapsed Structure Search and Rescue (CSSR) facilitated by the Miami-Dade Fire Rescue Department and OFDA of USAID. To date, a total of 54,520 community members have received urban volunteer training from BFSCD. According to the National Earthquake Contingency Plan currently, numerous public and private sector institutions are actively involved in earthquake risk management activities presented in Table 1.

Table 1: Public and Private Sector Institutions Actively Involved in Earthquake Risk Management Activities in Bangladesh (CDMP, 2009b).

Public Sector	**Private Sector**
Bangladesh Fire Service and Civil Defence	Federation of Bangladesh Chambers of Commerce
Bangladesh Police	Institute of Architects Bangladesh
Armed Forces Division	Anjumane Mofidul Islam
Bangladesh Ansar and VDP	
City Corporations and Authorities	NGOs like, CARE Bangladesh, Islamic Relief Worldwide (IR), Action Aid Bangladesh (AAB), Bangladesh Disaster Preparedness Centre (BDPC), Bangladesh Red Crescent Society (BDRCS) etc
Water Supply and Sewerage Authority	
Directorate of Relief and Rehabilitation	
Disaster Management Bureau (DMB)	
Bangladesh Power Development Board	
Bangladesh Telecommunications Company Limited	
Directorate General of Health Services	Electronic and Print Media
Dhaka Power Distribution Company	
Bangladesh Road and Transport Authority	Various Mobile Companies: Grameen Phone, AKTEL, Banglalink, CityCell, TeleTalk etc.
Geological Survey of Bangladesh	
Titas Gas Transmission and Distribution Co. Ltd	

5.0 Discussion

5.1. Mitigation Stage

5.1.1. Enforcement of Building Codes and Land Use Zoning

The primary cause of the ultimate failure of preparedness programs and the massive destruction in Turkiye and Morocco is non-compliance with updated building codes. Similar violations and non-conformities are also widespread in Bangladesh. Standard design principles, mixture proportions, reinforcements, setback rules, and land use zoning are often disregarded. Policies, rules, and regulations rarely reach the implementation stage. Therefore, proper implementation and monitoring of building codes are essential. The Bangladesh National Building Code 2020, the Town Improvement Act 1953, the Building Construction Act 1952, the Building Construction Rules 2008, the Land Development Rules for Private Housing 2004, and the Dhaka Metropolitan Detailed Area Plan (2016-2035) are some of the relevant policies concerning site selection and building design standards. Corruption, an inadequate number of building inspectors from RAJUK, lack of regular supervision, insufficient public awareness, cost-cutting tendencies among building owners, and the profit-driven attitudes of contractors and real estate companies contribute to building code violations. Thus, strong enforcement and monitoring are required. Retrofitting old and at-risk buildings is a pressing necessity. In Turkiye, collapsed buildings are often stacked closely together. However, in Bangladesh, it is common for buildings to lean even during low-magnitude earthquakes, often due to violations of setback rules, which also pose risks to adjacent structures. Along with implementation and supervision, penalizing violators is also essential..

5.1.2 Management of Flood Caused by Land Subsidence

Some areas of Turkiye experienced land subsidence and flooding. Since Dhaka is surrounded by rivers on all sides, a similar situation could occur here as well. Therefore, emergency flood control and management strategies must be integrated into policies and programs.

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5.1.3 Control of Post-Earthquake Fire Disaster

Turkiye experienced a post-earthquake fire disaster at Iskenderun Port (Paone, 2023). According to fire experts, the risk of a similar post-earthquake fire disaster is high in Dhaka. Controlling the flow of gas and electricity during an earthquake can significantly reduce the likelihood of post-disaster fires, as sparks from electrical short circuits can serve as ignition sources (Mohammadi et al., 1992). Therefore, buildings in earthquake-prone regions should be equipped with automatic or manual gas shut-off systems, as well as individual fire hydrants or water sprinklers (Mondal, 2019).

5.2 Preparedness

5.2.1 Capacity Building of Search and Rescue Team

As discussed, only 68 members from the BFSCD have received international training in Urban Search and Rescue Operations, which is minimal compared to the large population of Dhaka city. BFSCD has managed to train approximately 50,000 urban volunteers at the community level across the country. In contrast, in 2019, Turkiye provided training courses to 30,883 people in Kahramanmaras province (population 376,045) and 12,615 people in Gaziantep province (population 1,065,975) (AFAD, 2019; "Turkiye Population," 2023). AFAD has 81 provincial branches and 11 search and rescue units (AFAD, n.d.). Therefore, Bangladesh needs to enhance its manpower and capacity. More community members should be included in training programs, which should be conducted regularly. Instead of short 1-3 day courses, training should last at least 6-12 months to develop community rescue experts. Additionally, the names and details of trainees must be recorded for effective emergency communication and mobilization. Moreover, Bangladesh is not a member of the International Search and Rescue Advisory Group (INSARAG), a global network aimed at establishing minimum international standards for USAR teams and developing coordination methodologies for earthquake response. Turkiye has several light, medium, and heavy USAR teams that meet INSARAG standards, and Morocco has a heavy USAR team accredited by the same organization. Although Bangladesh does not have any officially enlisted INSARAG USAR teams, the rescue team members working in Turkiye have received training in INSARAG standards and have designated focal points. Despite having skilled and trained USAR teams, both Turkiye and Morocco struggled to execute prompt rescue operations, highlighting the risks that Bangladesh faces.

5.2.2 Modern Equipment

Moreover, as suggested by BFSCD experts, Bangladesh still lacks modern rescue and operational equipment, such as life detectors. The USAR teams from developed countries utilized advanced equipment during the rescue operations in Turkiye, which significantly increased the speed and chances of saving lives.

5.2.3 Widening of Roads

Rescue operations can be successfully accomplished if emergency vehicles have easy access to disaster sites, as seen in Turkiye. The narrow and congested road network in Dhaka city is a major hindrance to emergency response, with nearly 50% of the roads measuring less than 20 feet wide, according to GIS analysis of the DAP (2016-2035). This restricts access for efficient fire vehicles (Elahi, 2022). Therefore, the government must take initiatives to improve the existing road networks.

5.2.4 Increasing Open Space

The provision of emergency health services, temporary rehabilitation, relief distribution programs, and management of deceased individuals all require ample open space, which is lacking in Dhaka city. In Turkiye, earthquake victims were accommodated in tents, and temporary hospitals were established in open spaces, transforming the city into a 'tent city.' A similar scenario occurred in Morocco. In contrast, Old Dhaka has only 5% open and green space, while New Dhaka has 12% (Mowla, 2011), which needs to be increased.

5.2.5 Availability of Excavators

In the event of massive building collapses, relying on manual rescue operations can significantly extend operation time. Excavators expedite the process. Documenting a list of available excavators and mobilizing them to disaster-affected areas is a valuable lesson learned from the Turkiye earthquake. Currently, BFSCD has enlisted 4 excavators in Dhaka, 2 in Chattogram, and 1 in Sylhet, which is grossly insufficient.

5.3 Response Stage

5.3.1 Rapid Rescue Operation

In Bangladesh, due to the tropical hot and humid climate, dead bodies decompose much faster than in Turkiye and Morocco. In Turkiye, corpses were found intact even several days after the disaster, which facilitated identification and handover to families; this may not be the case in Bangladesh. Therefore, search and rescue operations must be conducted rapidly.

5.3.2 International Assistance

As of February 12, 2023, USAR teams from 83 countries, comprising about 10,423 individuals and 364 search dogs, were deployed in Turkiye to locate, extricate, and provide first medical assistance to victims trapped under collapsed structures at the request of the Disaster and Emergency Management Presidency (AFAD) (Türkiye Earthquakes Urban Search, 2023). In the Moroccan earthquake, countries such as the UK, UAE, Qatar, and Spain sent financial aid and rescuers to assist those in distress (Foreign Rescuers, 2023). In contrast, during the Rana Plaza disaster, the Bangladesh government rejected foreign assistance offered by INSARAG, which drew significant criticism (Bergman, 2013). In a race against time, countries affected by major disasters must actively seek international aid and rescue assistance.

5.3.3 Encouraging Community Participation

Even without modern equipment and state-of-the-art technology, Bangladesh's rescue team in Turkiye was successful and received global admiration. Their success was largely due to encouraging community participation, gathering information from locals about stranded civilians and possible locations of deceased individuals.

5.3.4 Promoting Civil-Military Coordination

Despite the massive damage caused by the twin earthquakes, Turkiye faced criticism for the delayed deployment of military forces in search and rescue operations. In the event of insufficient manpower, Bangladesh needs to ensure the rapid deployment and mobilization of military resources. In 2014, the Regional Consultative Group (RCG) on Humanitarian Civil-Military Coordination for Asia and the Pacific was established to enhance response preparedness planning, focusing on collaboration between civilian and military stakeholders in priority nations in the region, including Bangladesh (OCHA, 2018).

5.4 Recovery

5.4.1 Humanitarian Help and Aid Diplomacy

Turkiye received an unprecedented influx of humanitarian aid from international organizations and individual countries, largely thanks to President Erdogan's successful aid diplomacy. Turkiye extended its support in nearly all humanitarian crises and emphasized building bilateral relationships rather than focusing solely on multilateral organizations. This approach allowed for better control over deliveries and increased visibility on the ground. As a result, Turkiye succeeded in fostering relationships based on brotherhood and trust, which was its intention (Stepansky, 2023). While Bangladesh is fortunate to receive humanitarian aid during times of distress, it should invest more in developing diplomatic strategies and relationships with developed, neighboring, and Muslim countries. In 2017 alone, Bangladesh received donations from the United States (US$ 115,952,000), the United Kingdom (US$ 65,898,000), Sweden (US$ 26,324,000), the EU (US$ 25,341,000), and others (OCHA, 2018).

5.5 Framework for Learning Lessons from Disasters

The current study proposes a new framework for learning lessons from disasters that may enhance a country's disaster management efficiency as shown in Figure 6. This framework identifies four key elements—mitigation, preparedness, response, and recovery—to understand the root causes of a disaster. By analyzing the strengths and weaknesses of a disaster-affected country, other nations with similar vulnerabilities can conduct a comparative assessment of their existing mitigation initiatives, preparedness, response, and recovery capacities. The suggested framework aims to help others gain crucial lessons from the experiences of disaster-affected countries and apply them to their own disaster management initiatives.

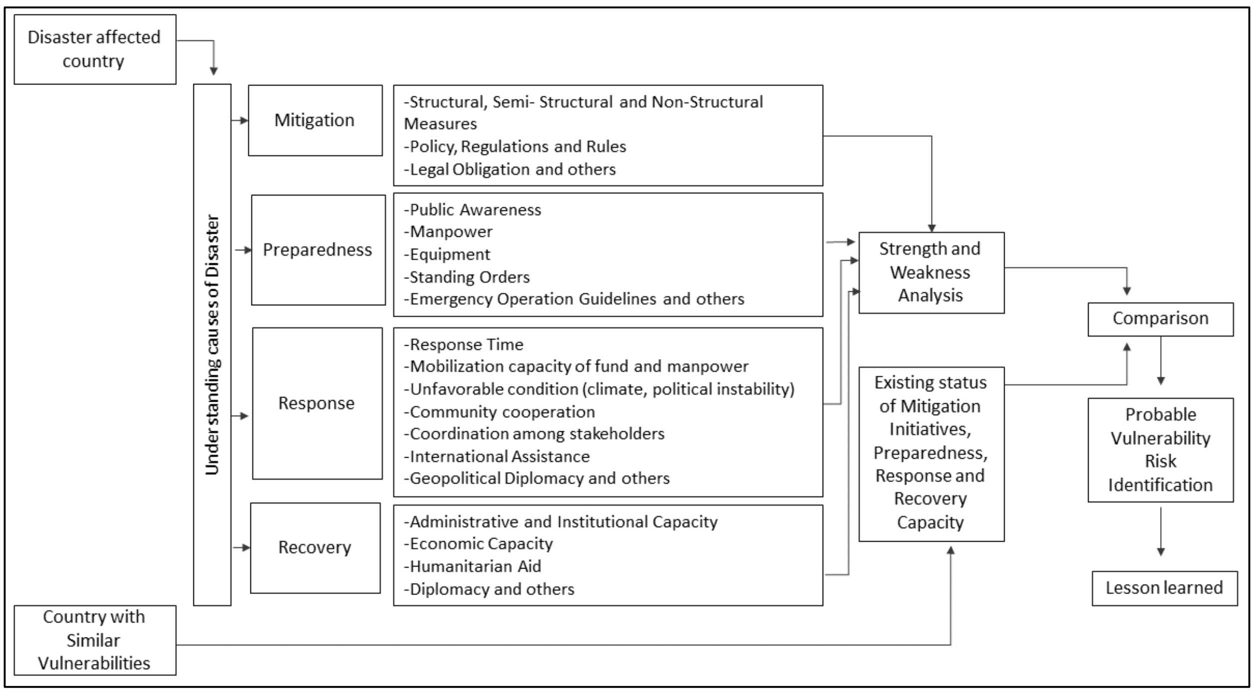

Figure 6: A Suggested Framework for Learning Lessons from Disasters, Not Limited to the Aspects Mentioned. The Spatial Context of Different Regions and Types of Disasters May Result in Changes to the Framework.

6.0 Conclusions

There is a strong possibility of a large earthquake disaster affecting Bangladesh. As observed from the Morocco earthquake, the potential for major earthquakes in relatively less active regions cannot be overlooked. The earthquakes in Turkiye and Morocco demonstrate how the expertise and experience of search and rescue teams, along with substantial funding, can be rendered ineffective due to significant damages primarily caused by neglecting building standards and zoning regulations. Therefore, it is imperative for Bangladesh to strictly enforce and supervise safety regulations for new infrastructure and to retrofit old and risky buildings. While achieving zero damage is impossible, recommendations include increasing and capacitating manpower, enhancing public awareness, and strengthening community resilience. Additionally, it is suggested to reduce emergency response times, improve coordination among stakeholders, promote community participation, and develop geopolitical strategies for managing humanitarian aid and assistance in disaster response.

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