Geospatial Vulnerability Assessment of Earthquake in District Mirpur Azad Jammu and Kashmir, Pakistan

Maryam Ayub[1], Warda Habib[2]

[1]National Engineering Services Pakistan
[2]The Urban Unit, Lahore, Pakistan

*Corresponding Author's Email: wardahabib419@gmail.com

Abstract

This study uses Geographic Information Systems (GIS) and the Analytical Hierarchy Process to estimate the geographical earthquake vulnerability of District Mirpur in Azad Jammu and Kashmir (AJK), Pakistan. Multiple environmental and physical markers, such as earthquake magnitude, depth, soil type, land use/land cover (LULC), elevation, proximity to fault lines, hospitals, roads, rivers, police stations, and educational institutions, were combined using a weighted overlay technique. Pairwise comparison matrices showed good consistency ratios (CR < 0.1), indicating the provided weights are reliable. The results show that earthquake magnitude (0.41) and earthquake depth (0.42) are the most influential environmental elements, whereas proximity to hospitals (0.27) and road networks (0.20) are the most important physical vulnerability criteria. The resulting seismic vulnerability map divides the research area into low, moderate, high, and extremely high vulnerability zones. Mirpur Tehsil was designated as the most dangerous location, with vital infrastructure such as Mirpur University of Science and Technology (MUST) and the Mangla Reservoir located in high-risk areas. The closeness of the Mangla Dam to active fault lines raises the possibility of secondary hazards such as dam outburst flooding. These findings highlight the importance of site-specific geotechnical research and targeted catastrophe risk mitigation initiatives. The created vulnerability maps are useful decision-support tools for urban planners, engineers, and disaster management authorities in improving earthquake preparedness and resilience in District Mirpur.

***Keywords**:* Seismic Vulnerability Assessment; Weighted Overlay; Random Consistency Index; GIS and UNISDR**.**

Introduction

Natural disasters, especially earthquakes, have the potential to inflict devastating consequences on communities, infrastructure, and economies. In regions like Mirpur, located in the seismic zone of Azad Jammu and Kashmir (AJK), Pakistan, the risk of earthquakes poses a significant threat to the populace (Habib et al., 2023). Understanding and quantifying this vulnerability is paramount for effective disaster preparedness and risk mitigation. The advent of geospatial technologies, encompassing Geographic Information System (GIS) and remote sensing, has revolutionized the assessment of vulnerability to seismic hazards, offering precise spatial analyses and data-driven insights (Aksha et al., 2020).

The region of Mirpur, AJK, has a history of seismic activity, making it imperative to conduct a comprehensive geospatial vulnerability assessment. Previous studies emphasize the importance of such assessments in disaster risk reduction (Smith, 2017) As urbanization and population density increase, the vulnerability of the region amplifies. A geospatial vulnerability assessment tailored to the unique context of Mirpur is necessary to identify high-risk areas, evaluate the susceptibility of critical infrastructure, and integrate socio-economic factors into the analysis (Kasperson et al., 2016)

Earthquakes are one of the most destructive natural hazards which cause physical and financial damage to humans and the environment worldwide. It occurs when there is sudden trembling (shaking) of the Earth's surface. Pakistan is in South Asia, which is prone to earthquakes due to its geographical position along the collision zone of the Indian and Eurasian tectonic plates. As a result, the country is experiencing frequent seismic activity. Earthquakes have had a significant impact on the country, causing loss of life, property damage, and economic disruptions (Hayes, 2017).

According to the statistics that was released by the Centre for Research on the Epidemiology of Disasters (CRED, 2015), the third most frequent natural disaster from 1994 to 2013 after landslide and flooding was earthquake occurrence, which resulted in about $787 billion of financial damage. In the last two decades the earthquake and also related disasters such as tsunamis are the deadliest natural disasters that are having a contribution of 55%(Nandi et al., 2018).

This earthquake resulted in widespread destruction across northern Pakistan and parts of Afghanistan and India. The loss was approximately 80,000 lives and left millions of people homeless. Entire towns and villages were reduced to rubble, and infrastructure such as roads, bridges, and buildings were severely damaged. Land sliding was also triggered by the earthquake which caused the formation of new lakes due to the blockage of rivers by landslide debris(Armaş, 2012).

Mirpur AJK (Azad Jammu and Kashmir), Pakistan, is situated in a seismically active region and has experienced destructive earthquakes in the past. As, the earthquake in 1987 having magnitude of 6.1 struck Mirpur AJK on October 18, 1987, which caused significant damage to buildings and infrastructure in the region and resulted in several casualties. Similarly, on October 8, 2005, there was a massive earthquake having the magnitude of 7.6 struck northern Pakistan, including Mirpur which had devastating impact on Mirpur (Gardezi et al., 2021). Thousands of people lost their lives, and many buildings and infrastructure were severely damaged or destroyed. However, the earthquake on September 24, 2019, was relatively moderate having magnitude of 5.8 and had damaging earthquake. Several people were injured, and there were reports of casualties (Habib et al., 2023).

Mirpur is seismically located in the active zone of the earthquake that is why it is an active zone to earthquake. So, it is important to do vulnerability assessment so that we can identify the earthquake prone areas. As identifying the earthquake prone areas, we may come to know where mitigation measures are to be applied for the vulnerability assessment to earthquake. It is difficult to evaluate the earthquake prone areas within the town to maintain and sustain the earthquake hazard and for mitigation strategies. This requires the use of

geospatial techniques, such as Geographic Information Systems (GIS) and Remote Sensing (RS), to collect, process, analyze, and visualize data related to the city's physical, social, and economic characteristics.

Study Area

Mirpur is a city located in the Azad Jammu and Kashmir region of Pakistan, known for its high seismic activity and vulnerability to earthquakes. The city has a population of over 450,000-500,000 people and is home to numerous buildings and critical infrastructure, such as hospitals, schools, and government buildings. It lies between 73.7537° E of longitude and 33.1480° N in latitudinal extent**.**

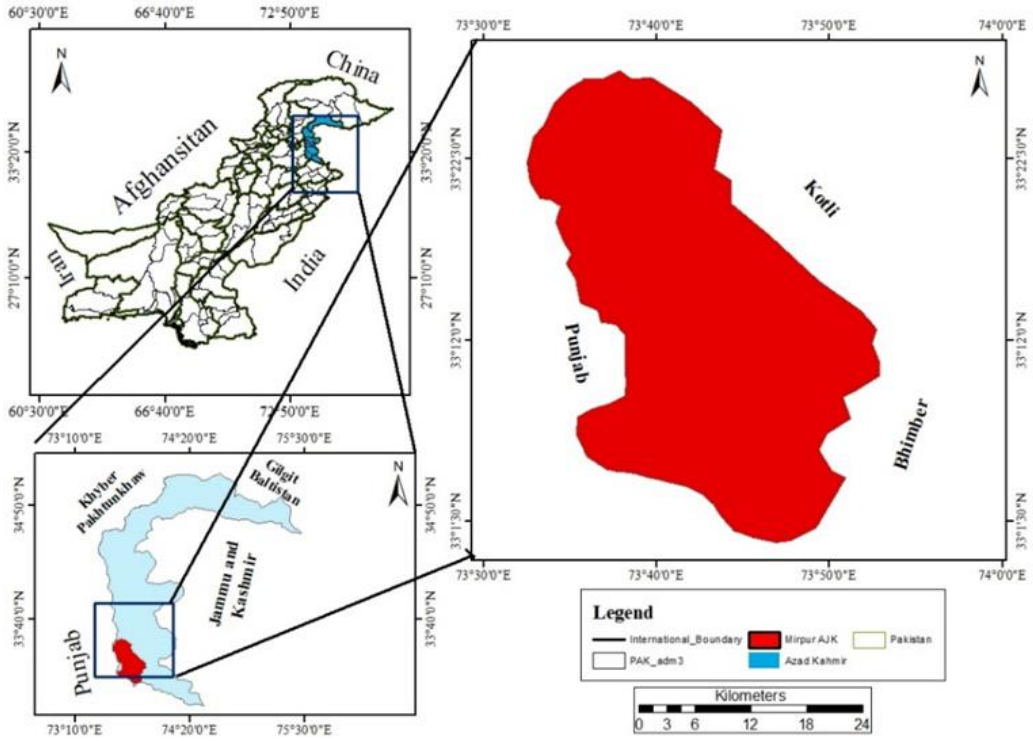

Figure 1: *Location of Study Area*

Geographically, Mirpur AJK is in the Upper Jhelum Valley, surrounded by the picturesque hills of the Pir Panjal range. It is situated approximately 175 kilometers (109 miles) south of Islamabad, the capital of Pakistan. The city lies at an elevation of around 459 meters (1,506 feet) above sea level. Mirpur AJK is renowned for its natural beauty, characterized by lush green landscapes, scenic valleys, and serene lakes. The city is also famous for its man-made reservoir called Mangla Dam, which is located on the Jhelum River, approximately 30 kilometers (19 miles) north of Mirpur. The dam not only serves as a major source of hydropower but also attracts tourists with its breathtaking views. The climate of Mirpur AJK is predominantly sub-tropical, with hot summers and relatively mild winters. The region experiences four distinct seasons, with summer temperatures ranging from 30°C to 45°C (86°F to 113°F) and winter temperatures averaging between 5°C and 15°C (41°F and 59°F). The monsoon season, from July to September, brings moderate to heavy rainfall to the area. In terms of demographics, Mirpur AJK has a diverse population comprising various ethnic and linguistic groups. The major languages spoken in the region are Urdu, Punjabi,

and Pahari. The city has witnessed significant emigration to foreign countries, particularly the United Kingdom, resulting in a substantial expatriate community known as the "Mirpuri diaspora."

Economically, Mirpur AJK plays a significant role in the overall development of Azad Jammu and Kashmir. The city's economy is primarily driven by agriculture, manufacturing industries, and remittances from overseas Pakistanis. Industries such as textiles, sports goods manufacturing, and construction are prominent contributors to the local economy. Mirpur AJK serves as a commercial and educational hub for the surrounding areas, with a range of educational institutions, healthcare facilities, and commercial centers. The city is well-connected through road networks, including the Mangla Expressway and the Mirpur-Kotli Dual Carriageway, which link it to other major cities in the region.

Materials and Methods

The objective of this study deals with the determination of the risk of the earthquake in an inclusive way, it is necessary to consider all the possible factors while researching for the seismic susceptibility. As a result, this study of the earthquake vulnerability can be determined by choosing the factors, like structural, social and physical distance for the necessity necessary services vulnerabilities (Shadmaan & Popy, 2023).

Earthquake Vulnerability Assessment (EVA) is a multi-criteria problem since earthquake damage is combined with a few variables including population density, gender, education level, building age, building density, building types, hospitals, police stations, road networks, open spaces etc. Hence, the multi-criteria are the assessing techniques that are used to resolve this issue. Population density, education level and gender falls under the social vulnerability whereas building age, building density and building types are under the structural vulnerability and hospitals, open spaces, police stations and road networks are under the physical distance that is needed to facilities vulnerability(Panahi et al., 2014). In this study, social indicators (population density, gender distribution, and education level) and structural indicators (building age, building density, and building construction type) were spatially mapped, normalized, weighted using the Analytical Hierarchy Process (AHP), and integrated into the GIS–AHP framework along with environmental and physical-distance indicators.

Table 1: Parameters for Vulnerability Assessment

Criteria	**Selected Factors**
Environmental	Land Cover Assessment
	Geology
	Elevation
	Depth of Earthquakes
	Magnitude of Earthquakes
	Soil Type
Physical	Distance to Hospitals
	Distance to Educational Institutes

	Distance to Police stations
	Distance from River
	Distance from Road networks
	Distance from Fault Lines
Social	Population Density
	Gender Distribution
	Education Level
Structural	Building Age
	Building Density
	Building Construction Type

The satellite image of Landsat 8 was downloaded from the USGS. The process of supervised image classification was applied. In the process, first training samples are collected and then theses samples are added in Maximum Likelihood tool in ArcGIS (Habib et al., 2020). The data of the other variables was digitized from the google earth pro and after then added the KML files to the ArcGIS to get the exact locations in the study area. Euclidean Distance was applied to find the distances from roads, hospitals, river, educational institutes, police station and fault line.

After the identification of the influential indicators by the AHP analysis, the indicators were assigned weights for the GIS-based overlay. Separate AHP pairwise comparison matrices were developed for social and structural indicator groups, and the derived weights were incorporated into the GIS-based weighted overlay analysis. This comparison is the conceptual complexity of the problem that is based on the level of the importance, which was published by the Saaty in 1977. According to the level of importance the weight of each component was calculated. Each parameter was assigned weight in AHP tool and final vulnerability map was generated. Figure 2 represents the complete research process.

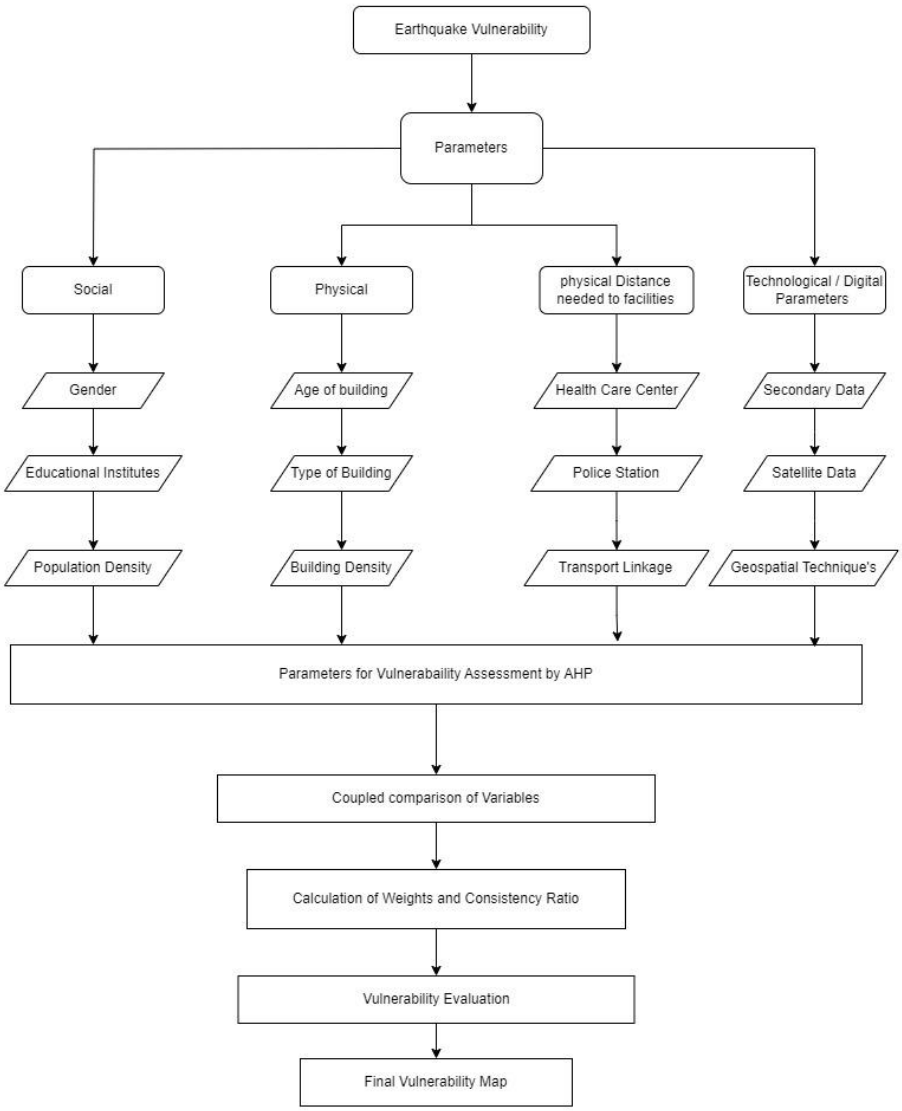

Figure 2. *Methodology Flow Chart*

Results & Discussion

Parameters for Vulnerability Assessment of Earthquake in Mirpur AJK

Among all the natural disasters the activity of the earthquake is increasing in both, rate of intensity and the rate of the occurrence during the last 10 years (USGS, 2015). There are many factors that are involved in increasing the natural disasters which in result provides social and economic loss. Mirpur AJK is an example of the area having mountains and having plain areas and valleys and it is also located near the Samwal-Jharik Kass active fault line and many other active fault lines which had multiple earthquake history. With the selected factors we can analyze the vulnerability assessment.

Physical Indicators

The elements such as, fire stations, hospitals, police station, road networks, disaster management centers and open spaces are taken under consideration to examine the physical

vulnerability assessment of Mirpur district which emphasizes the need of accessibility to necessary services(Shadmaan & Popy, 2023). The following table 2 shows the pair-wise comparison of physical parameters.

Table 2: Physical Factors with pairwise comparison matrix

Factors	Hospital	Road	Educational	River	Fault Line	Police	Weights	Rank
Hospital	1	2	3	2	3	7	0.27	1
Road	1/2	1	3	3	5	7	0.20	1/2
Educational	1/3	1/3	1	1	2	7	0.14	1/3
River	1/2	1/3	1	1	3	9	0.17	1/2
Fault Line	1/2	1/3	1	1	1	5	0.11	1/2
Police	1/7	1/7	1/7	1/9	2	1	0.02	1/7

Principal Eigen Value: 6.436446591

CR: 0.08728932

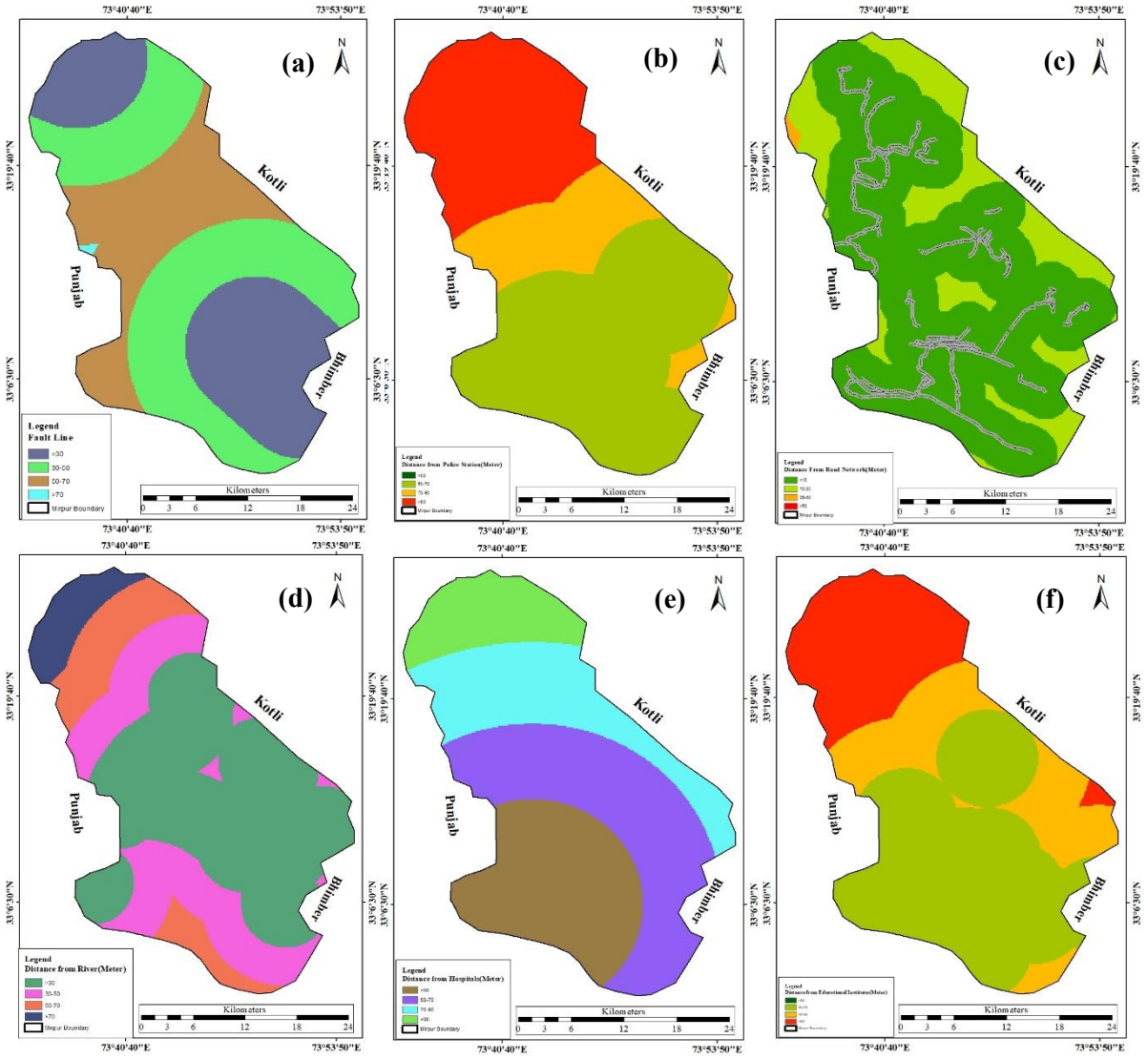

Figure 3: *Physical Parameters for Seismic Vulnerability Assessment*

Figure 3 shows the analysis of physical parameters for seismic vulnerability assessment in Mirpur AJK. Figure 3 a represents that Mirpur city is located at the active fault line namely Samwal-Jharik Kass. The image shows that Mangla reservoir lies in closer proximity to fault line. This finding indicates that Mangla Dam is prone to active seismic activities. So, there is possibility of Dam Outburst flooding, and it will badly affect the downstream population. Figure 3b is the map of distance to police stations. The image shows that Mirpur tehsil has more quick access to police stations as compared to Dadial tehsil. The road network is important permanent in disaster preparedness for evacuation. The figure 3c shows that Mirpur whole area has proper mode of transportation. One hazard can provoke other hazards too. Like earthquake activity in Mirpur district can lead to flooding. Most of the area of Mirpur city is located in closer distance to Mangla Reservoir (Figure 3d). Figure 3e shows access to hospitals. It is observed that Mirpur have unequal distribution of services.

Environmental Indicators

The elements such as earthquake magnitude, soil type, LULC, and elevation are taken under consideration to examine the environmental vulnerability assessment of Mirpur district

which emphasizes the need of accessibility to necessary services (Shadmaan & Popy, 2023). The following table 3 shows the pair-wise comparison of physical parameters.

Table 3: Pairwise Comparison Matrix of Environmental Parameters

Class	Earthquake Magnitude	Soil Type	Earthquake Depth	Elevation	LULC	Weights	Rank
Earthquake Magnitude	1	9	1	3	3	0.41	1
Soil Type	1/9	1	1/4	1/2	1	0.06	1/9
Earthquake Depth	1	4	1	7	2	0.42	1
Elevation	1/3	2	1/7	1	1/5	0.10	1/3
LULC	1/3	1/3	1/2	2	1	0.09	1/3

Principal Eigen Value: 4.213671959

CR: 0.07122399

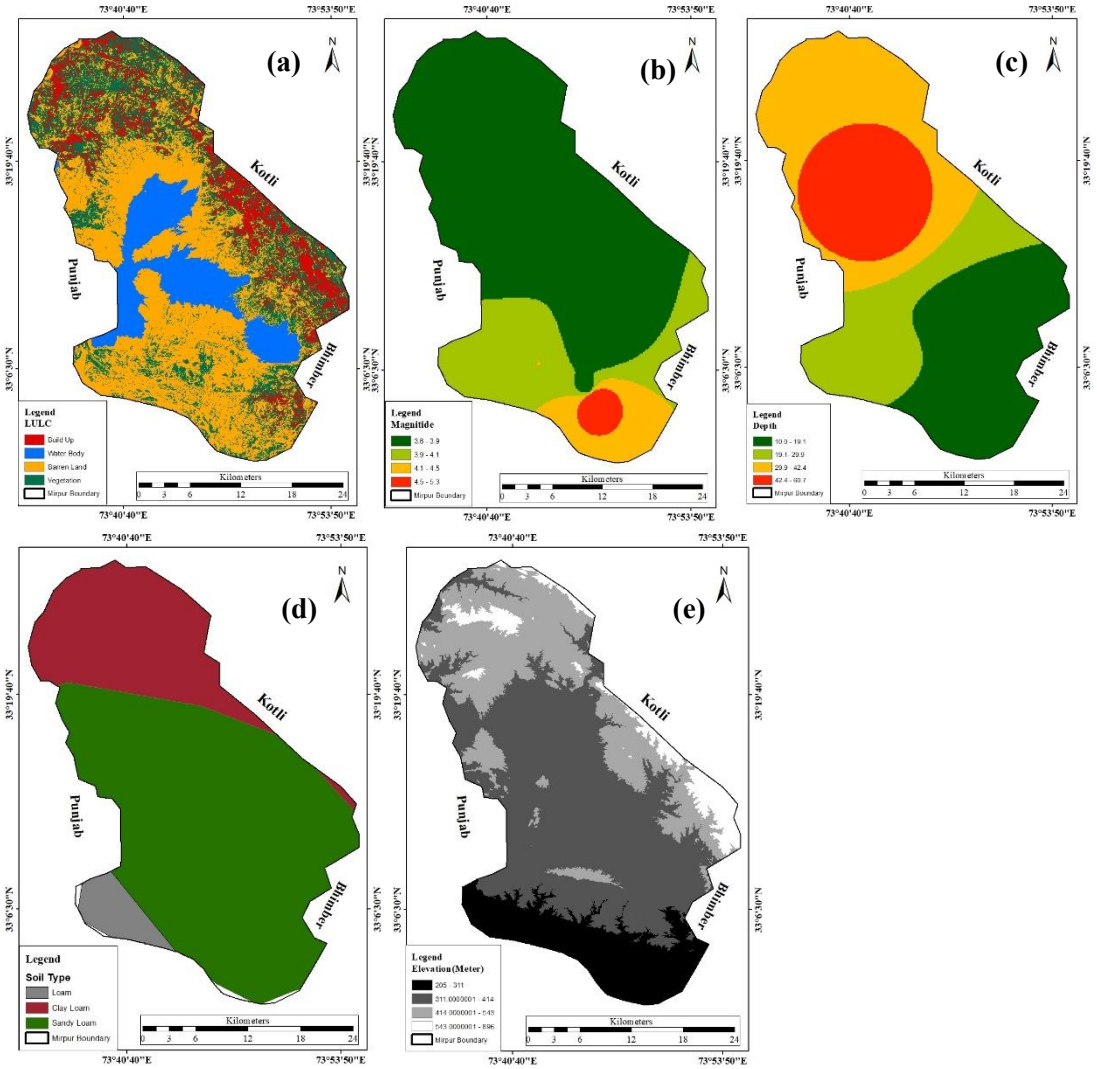

Figure 4: *Environmental Parameters for Seismic Vulnerability Assessment*

Figure 4 represents the assessment of all environmental parameters. Figure 4a shows Land Cover assessment of Mirpur City. The city is covered mostly by barren land whereas built up is only detected in northern and western regions. The water reservoir of Mangla dam can also be observed. The map (Figure 4b) shows that Northern part of Mirpur city experiences lesser magnitude earthquake as compared to southern area which experiences higher magnitude level seismic activities. It is observed that earthquake depth shows opposite trend in comparison to magnitude in Mirpur City (Figure 4c). The southern part faces higher depth of earthquakes whereas northern area observes earthquakes with lesser depth. Figure 4d shows that three types of soil are observed in Mirpur City. Red color is showing clay loam, grey color is showing the loam type of the soil while green color is showing the sandy loam type of the soil in Mirpur AJK. Elevation is an important factor which is considered while conducting the vulnerability assessment in a region, while it is not affecting the earthquake vulnerability but can have influence on other factors that are affecting to the vulnerability of earthquake. As, elevation is not affecting earthquake directly, but it is affecting the other factors such as, flood risk, land sliding and to the liquefaction potential which are affecting to the earthquake vulnerability preparedness efforts (Figure 4e).

Social Indicators

The elements such as population density, gender distribution and education level are taken under consideration to examine the social vulnerability assessment of Mirpur district. Social vulnerability plays a significant role in disaster risk because the ability of a community to respond, cope and recover from earthquake events depends largely upon demographic and socio-economic characteristics (Shadmaan & Popy, 2023). Areas having higher population concentration are more exposed to seismic risk, whereas gender imbalance and lower literacy level increase the vulnerability due to limited awareness and disaster preparedness capacity.

Table 4: Pair-wise Comparison Matrix of Social Parameters.

Class	Population Density	Gender Distribution	Education Level	Weights	Rank
Population Density	1	3	5	0.62	1
Gender Distribution	1/3	1	2	0.24	1/3
Education Level	1/5	1/2	1	0.14	1/5

Principal Eigen Value: 3.061
CR: 0.052

Figure 5: *Social Parameters for Seismic Vulnerability Assessment*

Figure 5 represents the spatial distribution of social parameters in Mirpur AJK. Figure 5a shows the population density distribution where the urban core of Mirpur city exhibits higher population concentration as compared to rural peripheries. Higher population density increases exposure and potential human loss during earthquake events. Figure 5b illustrates gender distribution across the study area. Areas with higher dependency ratio and socially vulnerable groups are more prone to disaster impacts due to reduced coping capacity. Figure 5c represents education level distribution. It is observed that areas with lower literacy rates show higher vulnerability due to limited awareness regarding earthquake preparedness, evacuation planning and emergency response strategies. Among all the social indicators, population density received the highest weight (0.62), indicating its dominant role in determining social vulnerability in Mirpur AJK.

Structural Indicators

Structural vulnerability is one of the most critical components of earthquake risk assessment because building characteristics directly influence the magnitude of damage during seismic events. The elements such as building age, building density and building construction type are taken under consideration to examine the structural vulnerability

assessment of Mirpur district. Older buildings, non-engineered constructions and high building concentration areas are more susceptible to collapse and structural damage during earthquakes (Panahi et al., 2014).

Table 5: Pair-wise Comparison Matrix of Structural Parameters.

Class	Building Age	Building Density	Construction Type	Weights	Rank
Building Age	1	2	3	0.5	1
Building Density	1/2	1	2	0.3	1/2
Construction Type	1/3	1/2	1	0.2	1/3

Principal Eigen Value: 3.024

CR: 0.041

Figure 6: *Structural Parameters for Seismic Vulnerability Assessment*

Figure 6 represents the assessment of structural parameters for seismic vulnerability in Mirpur AJK. Figure 6a shows the spatial distribution of building age where older constructions are mainly concentrated in central urban zones. These buildings are more vulnerable due to outdated construction practices and lack of seismic resistance measures. Figure 6b illustrates building density. High-density built-up areas increase structural interaction and cascading collapse risk during earthquakes. Figure 6c represents building construction types. Areas dominated by non-engineered masonry structures are more vulnerable as compared to reinforced concrete frame structures. Among all the structural indicators, building age received the highest weight (0.50), indicating its greater influence on structural vulnerability in the study area.

Seismic Vulnerability Zones

This study uses a combination of GIS and remote sensing to assess areas at risk for potential damage due to earthquakes. It includes all physical, seismological, and environmental aspects that may contribute to subsequent seismic events. The final EVA map of the study area (Figure 5) depicts earthquake-prone areas. According to the findings, Mirpur tehsil is in a higher-risk zone for earthquakes. Mirpur University of Science and Technology (MUST), the only university in Mirpur district, is also vulnerable to earthquakes. Most importantly, the Mangla reservoir is more susceptible to earthquake effects. This can result in dam outburst flooding in the future. This observation demonstrates that the Mirpur Ajk area is vulnerable to multiple hazards in the future. The findings highlighted the importance of comprehensive site-specific geotechnical assessment in this region. The final earthquake vulnerability map reflects the combined influence of environmental, physical-

distance, social, and structural indicators. Areas characterized by high population density, older building stock, and dense built-up structures exhibit higher vulnerability levels, even where environmental hazard intensity is moderate.

The produced map depicts the different levels of seismic risks in the study region; nevertheless, for quantitative earthquake hazard evaluation, more comprehensive and field-based research is suggested for marked areas as very high hazards on the developed EVA map. Thematic maps developed from several input parameters, their incorporation and representation with the Geographic Information Systems (GIS) tool, and the generation of the final potential map provide a quick, specific and accurate source of seismic risk assessment to society, urban planners, engineers, architects, and policymakers.

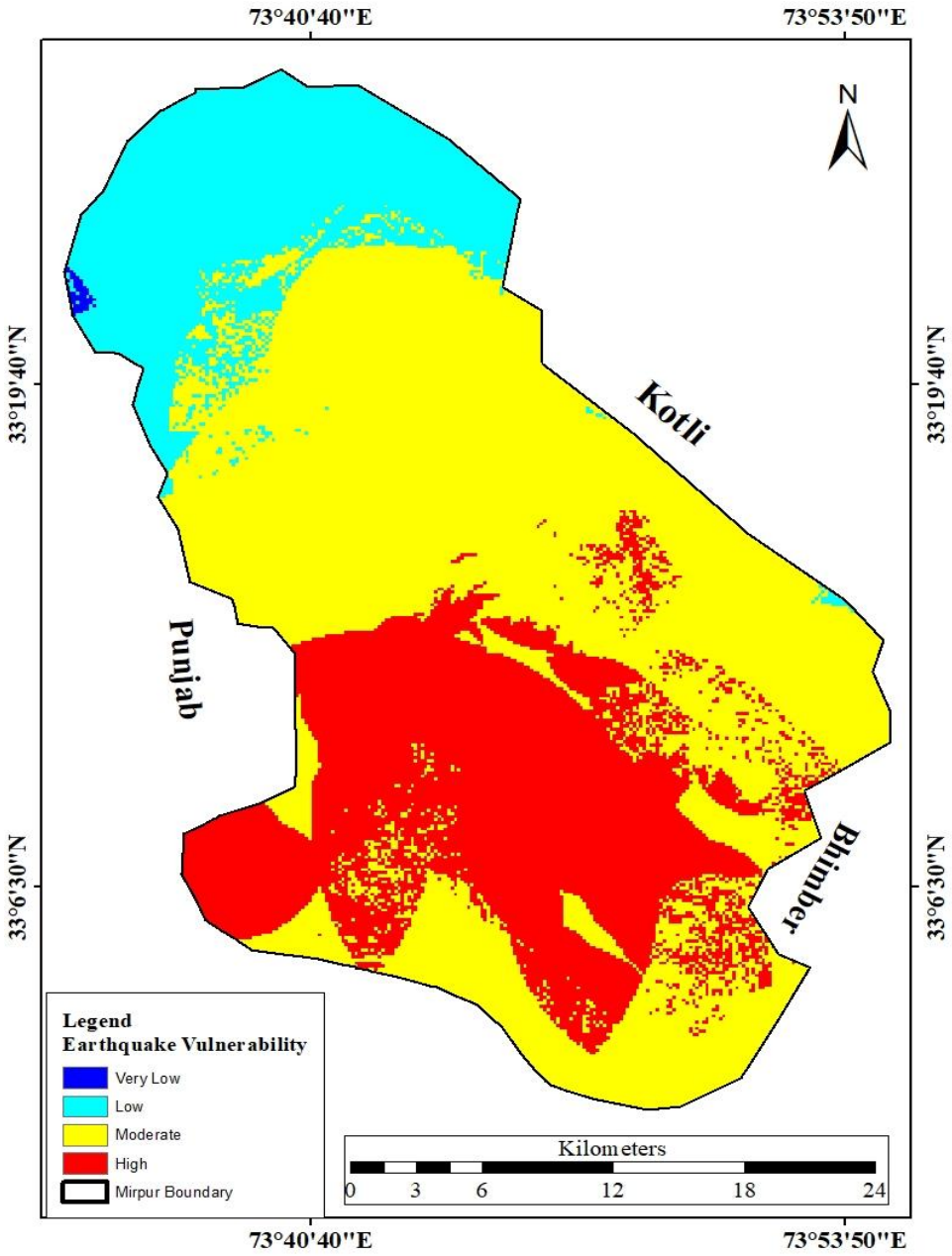

Figure 7: *Geospatial Vulnerability Assessment of Earthquake*

Earthquake Risk Reduction Plan (ERR) for Mirpur AJK

The abbreviation of ERR is an earthquake risk reduction while ERRP is abbreviated as earthquake risk reduction plan. This plan is made to avoid emergency situation during the earthquake. To develop the EER plan in Mirpur AJK required comprehensive approach which involves the public, local authorities, governmental agencies and community organizations. Tis plan should focus on the migration, response, recovery and preparedness. Here is he scheme plan for the earthquake risk reduction plan in Mirpur AJK:

Risk Assessment and Mapping

we should continue to monitor the seismic activity in this region. Detailed seismic maps should be developed to identify the high-risk zones. We should conduct vulnerability assessments of critical infrastructure, buildings, and lifelines.

Public Awareness and Education

Public awareness campaigns should be implemented for assessing the earthquake preparedness and also for earthquake risk. Regular earthquake training sessions should be done in schools, communities and offices.

Building Codes and Retrofitting

Building codes should be updated to ensure the construction practices that can mitigate the earthquake damage. Government should provide incentives to support the retrofitting of the existing old buildings that are highly vulnerable to the earthquake risk.

Early Warning Systems

Earthquake early warning should be installed in the region which can provide advance notice to residents. Educate the public on how to respond when they receive an earthquake alert.

Land Use Planning and Zoning

Public should be restricted to construct building at the areas that are under high-risk areas. Resilient urban planning should be promoted and land use practices to minimize exposure to earthquake hazards.

Emergency Response and Evacuation

Emergency response plan should be developed which includes the evacuation routes and shelters. Responders to the earthquake should be trained first and then response to the rescue techniques.

Community-Based Organizations

Community-based organizations and volunteer groups focused on disaster preparedness and response. Community Emergency Response Teams (CERTs) should be established to provide immediate assistance in the event of an earthquake.

Infrastructure Lifeline Protection

Strengthen lifeline infrastructure, such as water supply, transportation, and communication networks, to reduce post-earthquake disruption.

Develop redundancy and backup systems for critical services.

Funding and Resource Allocation

Sufficient resources and funding for earthquake risk reduction initiatives should be allocated.

Simulation and Modelling

Use earthquake modelling and simulation tools to better understand potential impacts and test preparedness measures. Creating a successful earthquake risk reduction plan for Mirpur AJK, it is required a coordinated effort across all levels of government and active participation from the community. Regular drills and exercises can help test and improve the plan's effectiveness. Additionally, ongoing public education and outreach are essential to ensure that residents are well-prepared and informed about earthquake risks and responses.

Structural factors causing earthquake vulnerability

Building density

In urban areas the assessment of the structural vulnerability is required which is used to decrease the level of damages caused by the earthquake. Several plans are there for the construction of the buildings. Generally, the areas that are having low rise with the vast surface areas are less vulnerable to the earthquake then the areas that are having high rise to the structures with smaller surfaces. The quality of the building material and the building surface area are equally significant to each other. The range of the buildings is from moderate to the large surface areas so that we can understand the earthquake-proof structure. Buildings are made up of the solar-dried mud brick having a lot of surface area that are more vulnerable. If the magnitude of the earthquake is above than the 6.0, then these mud brick structures can have collapsed with each other. As, for the EVA, the quality of the building material is very essential along the areas. The strategy of the flawless development can be reduced by the earthquake vulnerability (Panahi et al., 2014).

Building age

Building age was distinguished in the three groups:

- Those that are under 10 years
- Those that are between 10-30 years
- Those that is older than the age of 30 years

In recent ten years, the buildings that are constructed are the new buildings. Many residential complexes are constructed at the open spaces that are now being used for the residence areas. In Mirpur city there are 10-30-year-old buildings and that also results in the cities recent development. Most significantly, it is predicted that the building that are 30-year-old are more susceptible to the earthquake as they are not designed with the earthquake

engineering in mind. The areas that are crowded by large number of buildings are more vulnerable to the earthquake (Martin & Szeliga, 2010).

Types of building

The type of the building is determined by knowing the material that was used in the construction of the buildings. If the durable materials are used in the construction, then those buildings decrease the vulnerability and vice versa. In the event that the materials utilized in a structure are tough, the weakness of that area diminishes as well as the other way around. It's undeniably true that a portion of the structures in Mirpur are genuinely old and made utilizing old methods. Also, most of as of late fabricated structures have disrupted the development guidelines and standards. Since construction standards have not forever been adhered to, the structures are exceptionally seismic tremor inclined. A brief look at the earthquake clarifies which occurred in past years. In this way, considering the muddled review and the restrictions of the obtained information in Mirpur, underlying variables, for example, kinds of structures per statistics unit are considered. Most of the structures in the review region are made of block, concrete, iron, cement and steel structures. Thusly, the structures made of mud structures are viewed as less defenseless contrasted with the designs made of block, concrete, iron, cement and steel.

Physical distance factors causing earthquake vulnerability

According to the study, this shows that all the residents of the city are not having all access to the urban facilities. There is a large difference that how the facilities are spread along the different areas of the Mirpur city.

Disaster management centers

Regions that are near to the DM centers are more likely to get the service quickly than the area that is far from the disaster management centers. As the risk of earthquake is lower in the regions that are near to the disaster management centers. So, in an earthquake the areas that are populated or the vulnerable areas are required for the emergency facilities firstly needed assistance and then required to migrate from the affected area to the other area that results, the areas near to the DM centers that receive facilities quickly than the communities that are away from the disaster management centers.

Police stations

There is a lot of contribution of police stations at the time of disasters. These forces are always in action to serve to minimize the risk and the serve to the normal people at the time of natural disasters.

Hospitals

People that are living near to the hospital’s areas are more likely to get the treatment quickly then the people living far from the hospitals.

Road networks

As, the road network systems are the important to the critical infrastructures that are used for the sustaining systems and also aiding the country recovery. If the road network is good, then it can lead to minimize the losses after the phenomenon of the earthquake.

Open spaces

This is also important sources that are reducing the vulnerability to the earthquake. Vulnerability shows the increasing behaviors, with the decrease of open spaces (Bahadori et al., 2017).

Conclusion

Earthquakes are among the most hazardous disasters, causing massive damage. To ensure an effective post-disaster response, the potential consequences of the disaster in regions should be assessed in advance. Seismic vulnerability assessment enables experts to assess the potential damage from future earthquakes. Therefore, the aim of the study was to assess seismic vulnerability in Mirpur AJK. Mirpur AJK is located in the region that is having high seismic zones and is also highly prone to the seismic activity. The study was based on the physical and environmental indicators with different sub-indicators were used for the vulnerability assessment to earthquake. Multi-criteria decision making (MCDM) is a tool which is used to examine and evaluate the several criteria which includes analyzing, store and visualizing the data that is based on the decision-making criteria. The MCDM includes AHP analysis for the assessment of the vulnerability assessment of earthquake in District Mirpur AJK. The vulnerability assessment to earthquake was done by the Analytical Hierarchical Process (AHP). The final Earthquake Vulnerability Assessment map of the study area represents earthquake-prone areas. According to the findings, Mirpur tehsil is in a higher-risk zone for earthquakes. Mirpur University of Science and Technology (MUST), the only university in Mirpur district, is also vulnerable to earthquakes. Most importantly, the Mangla reservoir is more susceptible to earthquake effects. This can result in dam outburst flooding in the future.

The geospatial vulnerability assessment of earthquake risk in Mirpur AJK, underscores the importance of proactive measures to reduce vulnerabilities, enhance preparedness, and improve resilience in the face of seismic events. It is important for local authorities, policymakers, and the community to work together to implement effective earthquake risk reduction strategies and ensure the safety and well-being of the population.

References

Aghataher, R., Delavar, M. R., Nami, M. H., & Samnay, N. (2008). A fuzzy-AHP decision support system for evaluation of cities vulnerability against earthquakes. World Applied Sciences Journal, 3(1), 66-72.

Aksha, S. K., Resler, L. M., Juran, L., & Carstensen, L. W. (2020). A geospatial analysis of multi-hazard risk in Dharan, Nepal. Geomatics, Natural Hazards and Risk, 11(1), 88–111. https://doi.org/10.1080/19475705.2019.1710580

Alam, M. S., & Haque, S. M. (2022). Multi-dimensional earthquake vulnerability assessment of residential neighborhoods of Mymensingh City, Bangladesh: A spatial multi-criteria analysis based approach. Journal of Urban Management, 11(1), 37-58.

Alizadeh, M., Hashim, M., Alizadeh, E., Shahabi, H., Karami, M. R., Pour, A. B., Pradhan, B., & Zabihi, H. (2018). Multi-Criteria Decision Making (MCDM) Model for Seismic Vulnerability Assessment (SVA) of Urban Residential Buildings. ISPRS International Journal of Geo-Information 2018, Vol. 7, Page 444, 7(11), 444. https://doi.org/10.3390/IJGI7110444

Alizadeh, M., Ngah, I., Hashim, M., Pradhan, B., & Pour, A. B. (2018). A Hybrid Analytic Network Process and Artificial Neural Network (ANP-ANN) Model for Urban Earthquake Vulnerability Assessment. Remote Sensing 2018, Vol. 10, Page 975, 10(6), 975. https://doi.org/10.3390/RS10060975

Armaş, I. (2012). Multi-criteria vulnerability analysis to earthquake hazard of Bucharest, Romania. Natural Hazards, 63(2), 1129–1156. https://doi.org/10.1007/S11069-012-0209-2/METRICS

Bahadori, H., Hasheminezhad, A., & Karimi, A. (2017). Development of an integrated model for seismic vulnerability assessment of residential buildings: Application to Mahabad City, Iran. Journal of Building Engineering, 12, 118–131. https://doi.org/10.1016/J.JOBE.2017.05.014

Bahadori, H., Hasheminezhad, A., & Karimi, A. (2017). Development of an integrated model for seismic vulnerability assessment of residential buildings: Application to Mahabad City, Iran. Journal of Building Engineering, 12, 118-131.

Baig, H. A. A., & Rizvi, S. H. H. (2014). Seismic risk assessment , and understanding of earthquake occurrence using geographical information system technique. International Journal of Research and Innovations in Earth Science, 1(2), 2394–1375.

Bilal, A., Yasin, M., & Ali, A. (2017). THE GEOLOGY AND STRUCTURE OF NEOGENE ROCKS IN DADYAL AND ADJACENT AREAS, IN THE SUB-HIMALAYAS, AZAD JAMMU AND KASHMIR, PAKISTAN. Pakistan Earth Science Malaysia (ESMY), 1(1), 15–20. https://doi.org/10.26480/esmy.01.2017.15.20

Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for Climate Change Research. Tyndall Centre for Climate Change Research, February, 1–20.

Cutter, S. L. (1996). Vulnerability to environmental hazards. Progress in human geography, 20(4), 529-539.

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2012). Social vulnerability to environmental hazards. In Hazards vulnerability and environmental justice (pp. 143-160). Routledge.

Cutter, S. L., Mitchell, J. T., & Scott, M. S. (2010). Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. Http://Dx.Doi.Org/10.1111/0004-5608.00219, 90(4), 713–737. https://doi.org/10.1111/0004-5608.00219

Delavar, M. R., Moradi, M., & Moshiri, B. (2015). Earthquake vulnerability assessment for hospital buildings using a GIS-based group multi criteria decision making approach: a case study of Tehran, Iran. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 40, 153-157.

DISTILLED Global Assessment Report on Disaster Risk Reduction. (n.d.).

Fayaz, M., Romshoo, S. A., Rashid, I., & Chandra, R. (2022). Earthquake Vulnerability Assessment of the Built Environment in Srinagar City, Kashmir Himalaya, Using GIS. Natural Hazards and Earth System Sciences, 1-35.

Gardezi, S. A. H., Hussain, G., Neupane, B., Imran, M., Hamid, Q. Y., Ikram, N., ... & Asghar, H. (2021). Geological investigation of 5.6 MW Mirpur earthquake, northwestern Himalayas, Pakistan. International Research Journal of Earth Sciences, 9(1), 20-31.

Gavarini, C. (2001). Seismic risk in historical centers. Soil Dynamics and Earthquake Engineering, 21(5), 459–466. https://doi.org/10.1016/S0267-7261(01)00027-6

Habib, W., Aslam, R. W., Akram, M. A. N., Khalid, M. B., Abbas, W., Tahir, M. H., ... & Mirza, A. I. (2020). Assessment of temporal changes in landuse patterns by incorporating topographical parameters. International Journal of Sustainable Development, 2, 99-113.

Habib, W., Mahmood, S., Noor, S., Saleem, A., Siraj, M., & Ahmad, H. (2023). A post earthquake damage assessment using GIS in district Mirpur, Pakistan. Advanced GIS, 3(2), 53-58.

Hayes, G. P., & Briggs, R. W. (2017). Introduction to the special issue on the 25 April 2015 Mw 7.8 Gorkha (Nepal) earthquake. Tectonophysics, 714–715, 1–3. https://doi.org/10.1016/J.TECTO.2016.10.033

Islam, M. N. (2016). EARTHQUAKE RISKS IN BANGLADESH: CAUSES, VULNERABILITY, PREPAREDNESS AND STRATEGIES FOR MITIGATION. https://www.researchgate.net/publication/317558570

Jena, R., Pradhan, B., & Beydoun, G. (2020). Earthquake vulnerability assessment in Northern Sumatra province by using a multi-criteria decision-making model. International Journal of Disaster Risk Reduction, 46, 101518. https://doi.org/10.1016/J.IJDRR.2020.101518

Jena, R., Pradhan, B., & Beydoun, G. (2020). Earthquake vulnerability assessment in Northern Sumatra province by using a multi-criteria decision-making model. International journal of disaster risk reduction, 46, 101518.

Jena, R., Pradhan, B., & Beydoun, G. (2020). Earthquake vulnerability assessment in Northern Sumatra province by using a multi-criteria decision-making model. International journal of disaster risk reduction, 46, 101518.

Jena, R., Pradhan, B., Beydoun, G., Nizamuddin, Ardiansyah, Sofyan, H., & Affan, M. (2020). Integrated model for earthquake risk assessment using neural network and analytic hierarchy process: Aceh province, Indonesia. Geoscience Frontiers, 11(2), 613–634. https://doi.org/10.1016/J.GSF.2019.07.006

Jena, R., Pradhan, B., Beydoun, G., Sofyan, H., & Affan, M. (2020). Integrated model for earthquake risk assessment using neural network and analytic hierarchy process: Aceh province, Indonesia. Geoscience Frontiers, 11(2), 613-634.

Jena, R., Pradhan, B., Beydoun, G., Sofyan, H., & Affan, M. (2020). Integrated model for earthquake risk assessment using neural network and analytic hierarchy process: Aceh province, Indonesia. Geoscience Frontiers, 11(2), 613-634.

Kamal, A. . S. M. M. (2013). Earthquake Risk and Reduction Approaches in Bangladesh. 103–130. https://doi.org/10.1007/978-4-431-54252-0_6

Kassem, M. M., Mohamed Nazri, F., & Noroozinejad Farsangi, E. (2020). The seismic vulnerability assessment methodologies: A state-of-the-art review. Ain Shams Engineering Journal, 11(4), 849–864. https://doi.org/10.1016/j.asej.2020.04.001

Martin, S., & Szeliga, W. (2010). A catalog of felt intensity data for 570 earthquakes in India from 1636 to 2009. Bulletin of the Seismological Society of America, 100(2), 562–569. https://doi.org/10.1785/0120080328

Martins, V. N., e Silva, D. S., & Cabral, P. (2012). Social vulnerability assessment to seismic risk using multicriteria analysis: The case study of Vila Franca do Campo (São Miguel Island, Azores, Portugal). Natural Hazards, 62(2), 385–404. https://doi.org/10.1007/S11069-012-0084-X/METRICS

Martins, V. N., e Silva, D. S., & Cabral, P. (2012). Social vulnerability assessment to seismic risk using multicriteria analysis: the case study of Vila Franca do Campo (São Miguel Island, Azores, Portugal). Natural hazards, 62, 385-404.

Nandi, A., Mazumdar, S., & Behrman, J. R. (2018). The effect of natural disaster on fertility, birth spacing, and child sex ratio: evidence from a major earthquake in India. Journal of Population Economics, 31(1), 267–293. https://doi.org/10.1007/S00148-017-0659-7/METRICS

Panahi, M., Rezaie, F., & Meshkani, S. A. (2014). Seismic vulnerability assessment of school buildings in Tehran city based on AHP and GIS. Natural Hazards and Earth System Sciences, 14(4), 969–979. https://doi.org/10.5194/NHESS-14-969-2014

Panahi, M., Rezaie, F., & Meshkani, S. A. (2014). Seismic vulnerability assessment of school buildings in Tehran city based on AHP and GIS. Natural Hazards and Earth System Sciences, 14(4), 969-979.

Ramírez Eudave, R., Ferreira, T. M., & Vicente, R. (2022). Parameter-based seismic vulnerability assessment of Mexican historical buildings: Insights, suitability, and uncertainty treatment. International Journal of Disaster Risk Reduction, 74(March), 102909. https://doi.org/10.1016/j.ijdrr.2022.102909

Rashed, T., & Weeks, J. (2003). Assessing vulnerability to earthquake hazards through spatial multicriteria analysis of urban areas. International Journal of Geographical Information Science, 17(6), 547-576.

Rezaie, F., & Panahi, M. (2015). GIS modeling of seismic vulnerability of residential fabrics considering geotechnical, structural, social and physical distance indicators in Tehran using multi-criteria decision-making techniques. Natural Hazards and Earth System Sciences, 15(3), 461-474.

Shadmaan, M. S., & Popy, S. (2023). An assessment of earthquake vulnerability by multi-criteria decision-making method. Geohazard Mechanics, 1(1), 94–102. https://doi.org/10.1016/j.ghm.2022.11.002

Shadmaan, M. S., & Popy, S. (2023). An assessment of earthquake vulnerability by multi-criteria decision-making method. Geohazard Mechanics, 1(1), 94-102.

Sharifikia, M. (2010). Vulnerability assessment and earthquake risk mapping in part of North Iran using geospatial techniques. Journal of the Indian Society of Remote Sensing, 38, 708-716.

Received:
Revision Received: February 14, 2026.