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Review Article

A Review of South-East Asian Countries' Earthquake Hazard Risk, Vulnerability & Capacity Analysis

Neelay Srivastava [1,*], Indrajit Pal [2], Ranjan Kumar [3]

[1] PhD Candidate, Disaster Preparedness, Mitigation and Management, Asian Institute of Technology Pathum Thani-12120, Thailand
[2] Associate Professor, Disaster Preparedness, Mitigation and Management, Asian Institute of Technology Pathum Thani-12120, Thailand
[3] Disaster Management Specialist, National Institute of Disaster Management (NIDM), Vijayawada, India

**Corresponding Author: neelaylko1@gmail.com*

Abstract

South East Asia, hosting 40% of the world's impoverished, grapples with multifaceted challenges ranging from poverty to urbanization. This research seeks to understand the region's risk to earthquake hazards, identifying areas demanding immediate intervention. Notably, earthquake repercussions often span multiple countries, necessitating coordinated regional responses. The Indonesian and Philippine archipelagos manifest high seismic hazards, contrasted by the moderate risks in the Malaysian peninsula. The study employed the "Index for Risk Management - INFORM" technique to assess vulnerability based on socio-economic and other relevant elements. The results indicated varied consequences among countries, with Myanmar identified as one of the most vulnerable, followed by Nepal and Bangladesh. Meanwhile, the Maldives emerges as the least at risk. Myanmar's human indices display significant vulnerability, with DPR Korea and Bhutan also requiring attention. Countries like Myanmar and Nepal exhibit reduced coping capacities, heightening their risk. In contrast, nations like the Maldives and Thailand benefit from robust disaster-mitigating infrastructures. Alarmingly, Nepal, India, and Indonesia are falling under the vicinity of seismic hotspots. The study encourages policy reform, strengthened emergency preparedness, and modified land-use planning that incorporates seismic risk to strengthen regional resilience.

Keywords: Seismic, hazard, South-East Asia, Disaster, Earthquake, Risk Index, Vulnerable, Coping Capacity

1 Introduction

The region of Southeast Asia exhibits significant diversity in various aspects, including its geographical features, population demographics, natural resource endowments, socio-cultural heritage, linguistic diversity, historical experiences of colonization, levels of economic development, and governmental structures (Daniels et al., 1992; Gardner et al., 2010). The region consists of a total of eleven countries, namely Bangladesh, Bhutan, the Democratic People's Republic of Korea (DPRK), India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, and Timor-Leste (Das & Nayar, 2021; Taw, n.d.). Within the region, there exist three nations whose population surpasses the threshold of 100 million individuals. (Samad MA, n.d.; Thomas et al., 2013). But it's important to note that in three other countries in the region, the population is less than 2 million. These countries include Timor-Leste with a population of approximately 1.78 million, Bhutan with a population of around 754,000, and Maldives with a population of approximately 345,000. This statement highlights a singular aspect within a broader spectrum of situations that must be taken into account when conducting comprehensive mapping and when formulating and executing catastrophe risk reduction or healthcare initiatives in the given region.

The member countries of the South-East Asian Region (SEAR) collectively accommodate almost 40% of the worldwide population living in poverty(Organization, 2006; Tiquio et al., 2017). These individuals encounter a range of complex issues, such as economic deprivation, limited educational opportunities, high unemployment rates, gender disparities, inadequate access to clean drinking water and sanitation facilities, migration obstacles, urbanization pressures, and the impacts of globalization. The Southeast Asian (SEA) region has persistently faced various threats and has created strategies to alleviate their effects over several centuries (Dilley, 2005; Hall et al., 2011; Payn et al., 2015). The hazards include a broad range, such as seismic activities like earthquakes and landslides in the northern Himalayas region. The Plains are vulnerable to both droughts and floods, while cyclones and storms from the Indian Ocean and the Bay of Bengal pose additional threats. Many countries in the region possess common geological formations, river basins, and coastal zones, leading to natural hazards that frequently transcend national boundaries.

Flooding is the primary catastrophic event in Southeast Asia, impacting a significant population, as indicated by the Emergency Events Database (EMDAT) of 2017 and the Global Assessment Report on Catastrophe Risk Reduction (GAR) of 2015. These incidents not only exhibit a high frequency but also have a significant influence on a substantial population, particularly individuals residing near rivers within the area. In the past decade and recent years, there has been a notable escalation in the occurrence and intensity of disasters in the Southeast Asian (SEA) region, namely those stemming from geological and hydro-meteorological factors (Debele et al., 2019; Kafle, 2017; Samphantharak, 2014). However, significant progress has been achieved in the realm of disaster management within this region. A notable positive development observed after the previous decade was the significant progress made by numerous countries in the region as they formulated and implemented national policies and strategies related to disaster management. These policies have acknowledged the governmental role associated with catastrophe management.

2 Study Area and Approach

The region of Southeast Asia encompasses a total of eleven countries, namely Bangladesh, Bhutan, the Democratic People's Republic of Korea (DPRK), India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, and Timor-Leste(for South-East Asia, 2020).

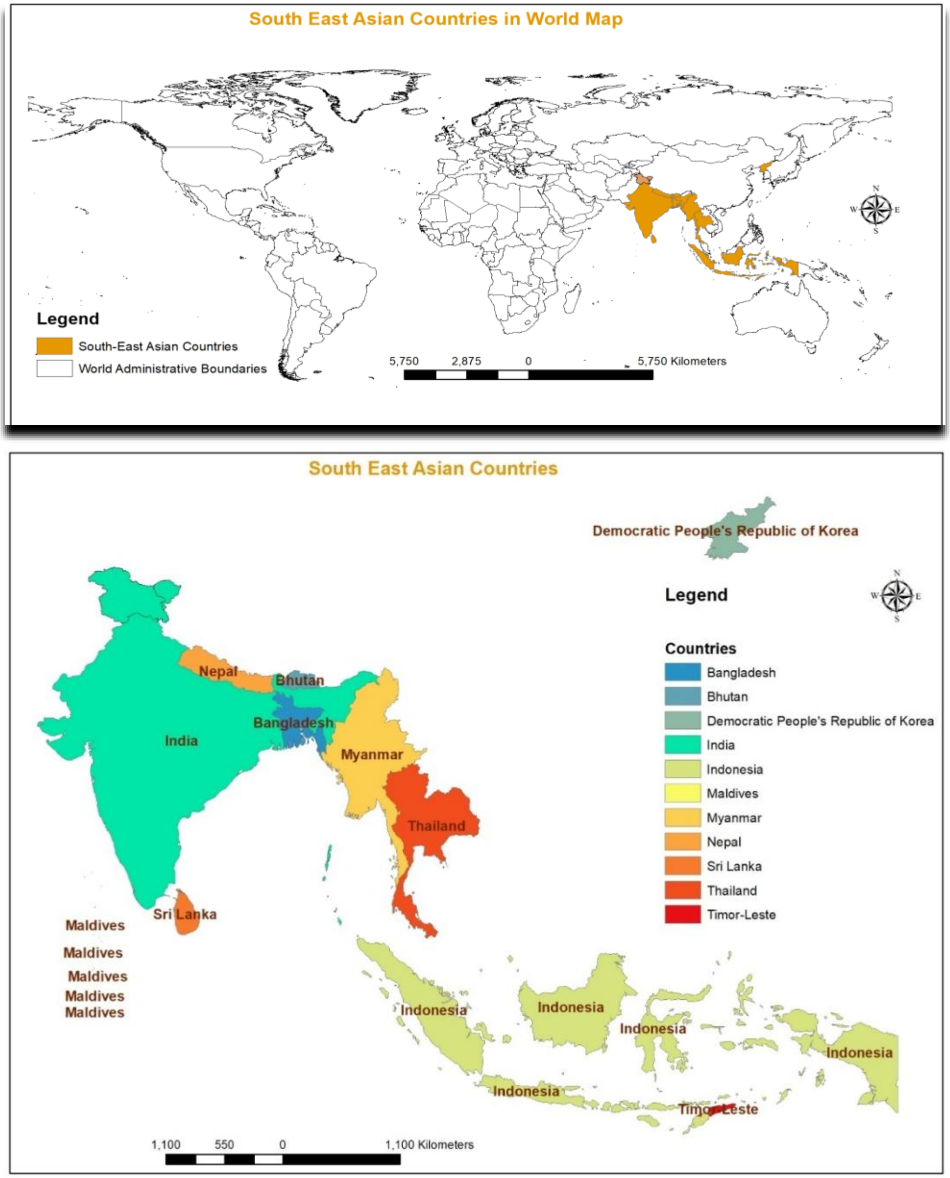


Figure 1: SEAR member countries (Source: Countries List - Northern Illinois University, Center for Southeast Asian Studies)

The aim of this study is to investigate and analyze the specific objectives and goals that are to be achieved through this research conducted. This study aims to present a comprehensive analysis of earthquake hazards and risks in the South East Asian region. The primary objective is to establish a risk profile that encompasses the many dangers associated with earthquakes and evaluate them in relation to the existing capacities within the region. The second main objective is to assess the comprehensive vulnerability and limited coping capacity within the region. The subsequent actions to be outlined pertain to addressing these identified weaknesses.

2.1 Approach for Risk Profiling

This study employed methodology and data from the "INFORM Index for Risk Management," a composite indicator created by the Joint Research Centre (JRC), in addition to the INFORM Index, EMDAT, GAR, and the Global Risk Data Platform. This open-source application is meant to help people understand the risks that come with disasters and humanitarian situations (De Groeve et al., 2015; Hazelkorn et al., 2018; Visser et al., 2020). In order to perform a thorough risk analysis, it is essential to give preference to the use of quantitative datasets. The approach based on the reviewing the inform index methodology that has integrated all essential criteria for risk assessment, including three principal dimensions. The current study focusses on the examination of hazards and exposure, specifically hazards that could lead to disasters and the associated population at risk. The hazards information is derived from "Global Risk Data Platform".

Exposure to hazards is influenced by socioeconomic factors, including population growth and density in hazard-prone areas, economic growth and development in the surrounding region, and the concentration of valuable assets and essential resources in rapidly growing megacities and secondary cities. (Kashem et al., 2016; Marin & Modica, 2017).

2.2 The assessment of communities' vulnerability to hazards.

The vulnerability of exposed assets in Southeast Asia (SEA) is increasing, mostly due to two main factors. First, poorly managed development practices have made it harder for people to deal with the negative effects of hazard events. Second, environmental issues, like climate change, have also made this situation more dangerous. One of the main reasons why an issue has an effect is because people don't have the ability to cope with it, which means they don't have the resources to lessen its consequences.

The coping capacity is not very considerable due to numerous major causes.

a) The Economic State of Southeast Asia b) Putting money into the healthcare sector to get ready for emergencies

c) The general public doesn't know much about it, and the government isn't very interested in it (Keim, 2008; Perry & Lindell, 2003).

The approach for calculating the concept of risk can be articulated as the result of three components: hazard and exposure, vulnerability, and insufficient coping capacity. (Birkmann, 2007; Birkmann & Welle, 2015; Dewan, 2013), which is as follows:

Risk = (Hazard & Exposure) x (Vulnerability) x (Lack of Coping Capacity)

The equation is changed to include the INFORM Risk method, which breaks the vulnerability variable down into three dimensions.

$$Risk = Hazard\ \&\ Exposure^{1/3} \times Vulnerability^{1/3} \times Lack\ of\ coping\ capacity^{1/3}$$

The equation in question is a multiplicative equation that has been adapted from the UNISDR equation of risk in order to incorporate the variable of Vulnerability, which has been further divided into three distinct dimensions. If any of the aforementioned dimensions possess a value of zero, the corresponding risk will be rendered as zero. The ranking level is determined based on the concept level, specifically focusing on dimensions. Functional level can be categorized into different categories. The component level refers to a collection of indicators that effectively encapsulate the essence of each category, enabling a more accurate and detailed analysis.

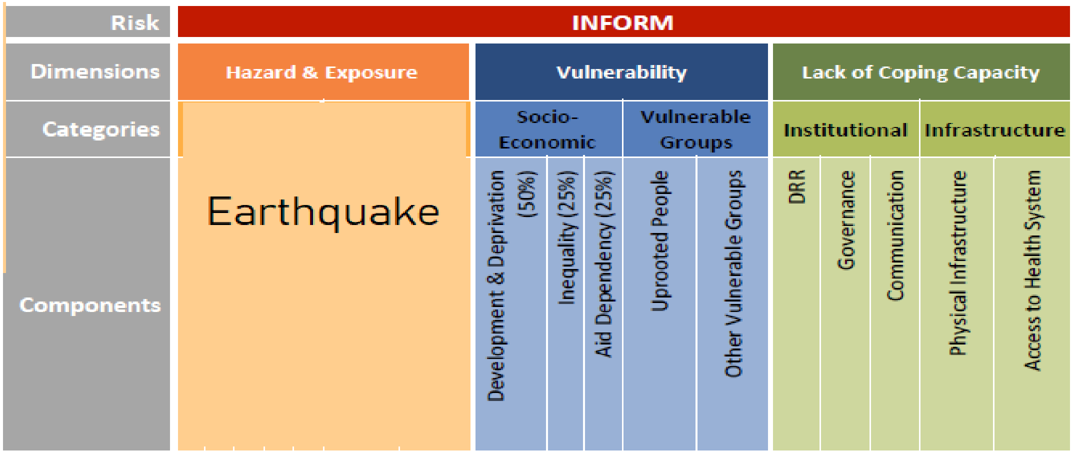
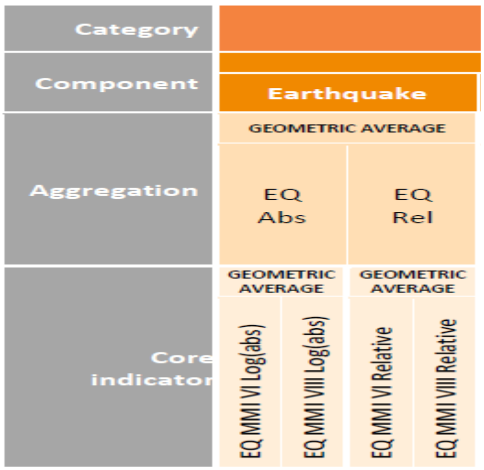


Figure 2: The metrics utilized in INFORM 2016 to assess natural hazard risk are expressed in terms of the Exposed Population (EP) or the Average Annual Exposed Population (AAEP).

The utilization of the composite indicator methodology was implemented due to its inherent benefits in addressing the limitations of the danger zone definition. This approach also accounts for locations characterized by high intensities as a distinct event type, with an equal likelihood of occurrence. The ultimate hazard component indicator is calculated as the geometric mean of the normalized AAEP obtained from two danger zones with different levels of minimum intensity, specifically low and extreme. The presence of a high danger component indicator is attributed to elevated values in both levels of intensities. When the indicator for high intensities is low, it will result in a fall in the indicator for low intensities. This suggests that even though there is a high number of persons exposed, the proportion of afflicted individuals is anticipated to be relatively smaller.

Component	Indicator	Source	MIN - MAX	No. of Missing Values
Earthquake	Physical exposure to MMI VI earthquake (absolute)	GSHAP	Log(10) - Log(10E5)	-
	Physical exposure to MMI VI earthquake (relative)	GSHAP; LandScan	0% - 0.2%	-
	Physical exposure to MMI VIII earthquake (absolute)	GSHAP	Log(10) - Log(10E4)	-
	Physical exposure to MMI VIII earthquake (relative)	GSHAP; LandScan	0% - 0.1%	-



Aggregation of the Earthquake Hazards category

Absolute- absolute value of physical exposure (AAEP)

Relative- relative value of physical exposure (AAEP per capita). AAEP is normalized with the country's population.

Figure 3: Indicators of the Earthquake Hazard category

The topic of vulnerability can be classified into various categories. The geometric average is utilized to aggregate two categories, namely Socio-Economic Vulnerability and Vulnerable Groups. The Socio-Economic Vulnerability category mostly pertains to the overall demographic characteristics of a country, whereas the Vulnerable Group category specifically encompasses socioeconomic groups that face restricted access to social and healthcare services (Iglesias et al., 2009; Malakar & Mishra, 2016).

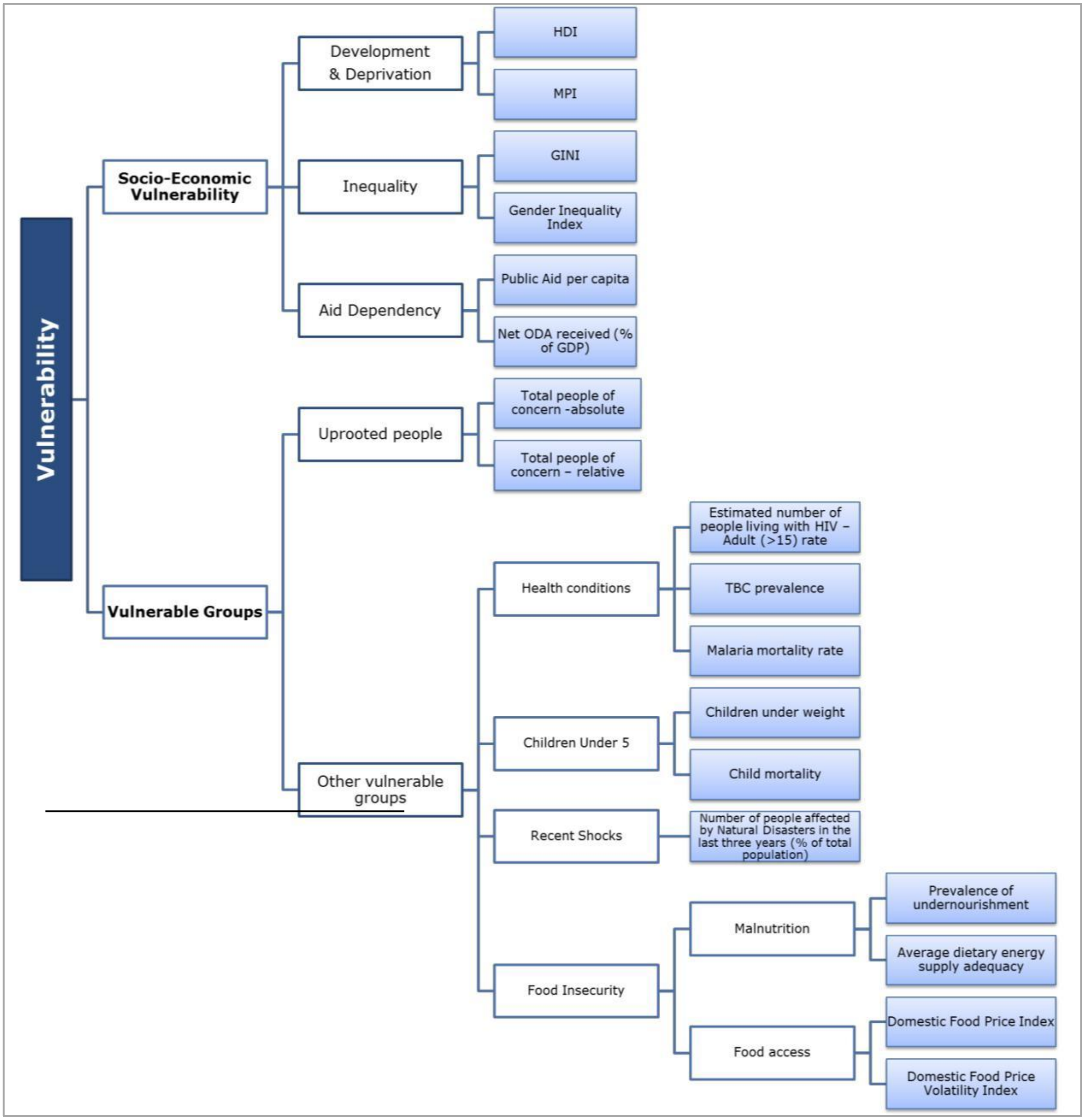


Figure 4: Graphical presentation of the Vulnerability dimension

2.3 Lack of Coping Capacity categories

The aggregation process involves calculating the geometric mean of two distinct groups, namely Institutional and Infrastructure. The Institutional category pertains to the presence of disaster risk reduction (DRR) programs. Governance issues within this category primarily focus on mitigation, preparedness, and early warning efforts. The infrastructure category evaluates the capacity for emergency response and recovery, including communication systems, physical infrastructure, and access to the health system (Daramola et al., 2016; Haque et al., 2020; Khan et al., 2022; Parsons et al., 2016; Wong et al., 2020).

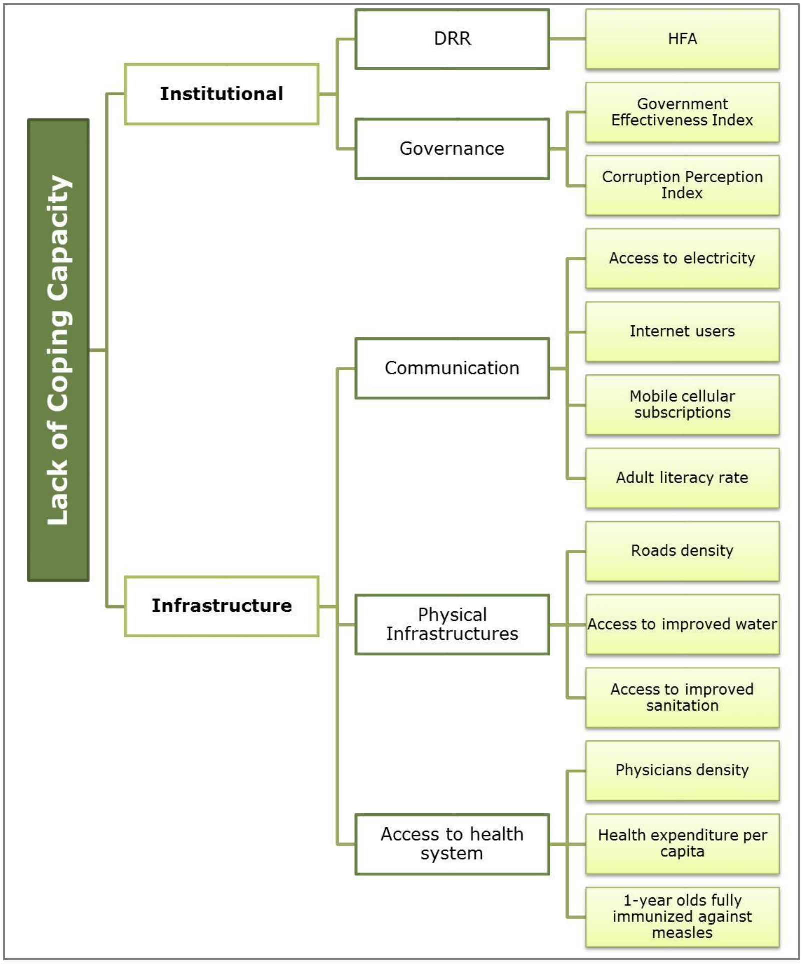


Figure 5. Graphical presentation of the Lack of Coping Capacity dimension

The composite indicator provides a concise viewpoint, and it is important for users to acknowledge its limitations. The rating of the index is derived from a mathematical synthesis of various individual indicators. It is worth noting that the INFORM index solely encompasses the dimensions that may be quantified using its indicators. The prioritization of data-driven judgments over user demands may be influenced by adherence to selection criteria. The categorizations of indicators encompass: Direct measures, such as quantitative indicators, have a significant impact on the score, as exemplified by the number of displaced individuals (Hazelkorn et al., 2018; Walters, 2016).

Proxy measures are commonly used in academic research to provide an indication or representation of certain phenomena. One such example is the Gini index, which serves as a surrogate measure for assessing disparities in education or health. These proxy measures play a significant role in the process of evaluating various entities or variables.

Composite indicators are constructed by combining direct and proxy measurements, as seen in aggregates such as the Human Development Index (HDI) or the Multidimensional Poverty Index (MPI) (de Muro et al., 2011; Duclos & Tiberti, 2016). INFORM provides nation rankings and categorizes them into five risk levels, from extremely low to very high vulnerability to humanitarian events. The INFORM Model, prevalent in academic analysis, necessitates pre-processing on core indicator raw values to derive composite indicators and sub-indices. This involves transforming raw data into indices through specific mechanisms.

Data management and transformation are based on a few key steps. First, imputation is used to fill in any missing numbers in the dataset. After that, the data is changed to a non-dimensional scale, which is usually shown as a percentage or as a per head amount. After that, logarithmic changes are used to make sure that the data is consistent and normal. The dataset is improved even more by rescaling it with the min-max normalisation method, which makes sure that all of the numbers are between 0 and 10. Last, outlier management is used, and clear "minimum" and "maximum" numbers are set. (De Groeve & Luca Vernaccini, 2014; Nagy et al., 2018).

The indicators were aggregated using several ways to determine their contributions to the composite metric. The established regulations entail the sole use of either the maximum or minimum value, along with the mathematical and geometric means. Mathematical and geometric aggregation methods were employed to integrate weights, derived from a theoretical framework, to modify the impact of each indication on the composite. The designated weights reflect a precisely evaluated equilibrium among many indicators.

This section intends to interpret the INFORM Index scores. The INFORM index features a rating range from 0.0 to 10.0, where lower scores signify more effective management of humanitarian hazards, while higher scores indicate the existence of issues. The classification of risk categories was performed using data gathered from 2011 to 2015. The classification was conducted for each category, dimension, and the comprehensive INFORM risk score. To create a Risk Map, data sets from 11 countries, including those in the South-East Asia Region (SEAR), were utilised. The transition from four to five classes in recent versions achieved two objectives: maintaining a balanced risk assessment and enabling manageable class sizes. The hierarchical risk classification is essential for uniform risk identification and provides improved risk monitoring and management (Renn, 1992, 2011). Due to inherent ambiguity in similarity-based risk classification, institutions should customise risk class definitions to align with their objectives and the specific risk decisions they face.

2.4 South East Asian Regional Vulnerability and Capacity Profile

2.4.1 Socio-Economic Vulnerability

The first part of the evaluation framework is about development and deprivation, which is worth 50% of the total. The issue of inequality is weighted at 25%, whereas the problem of aid dependency is weighted at 50% (DE et al., 2014). Quantitative and effective indicators have been utilised to evaluate and measure the vulnerability aspect of the Southeast Asian (SEA) region.

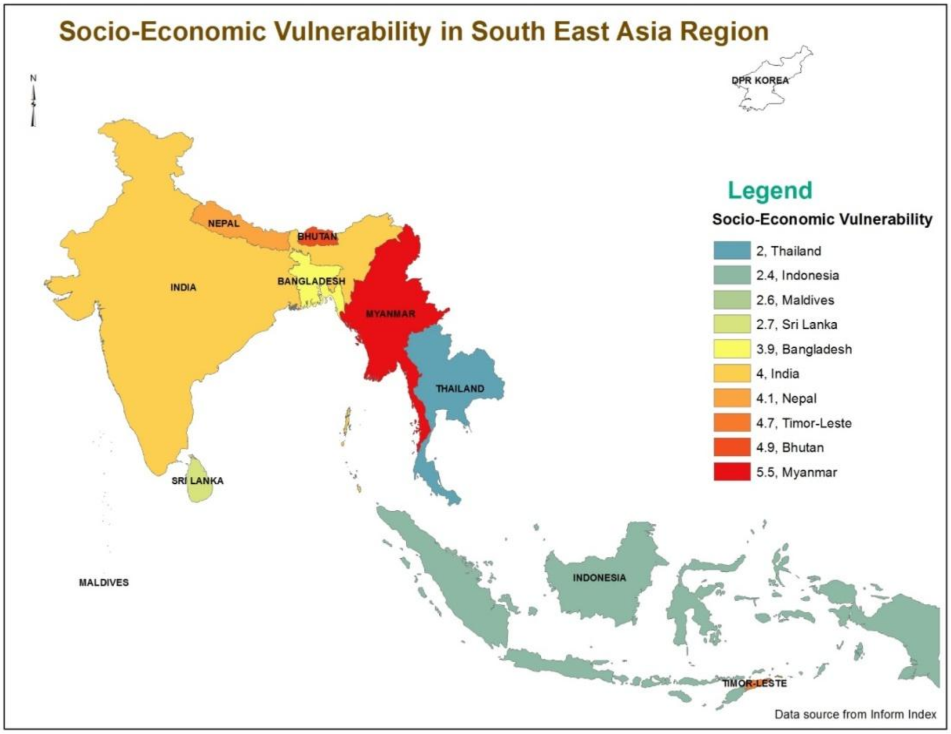


Figure 6: Socio-Economic Vulnerability of SE Asian Countries

The overall vulnerability score is made up of two parts: Socio Economic Vulnerability and other susceptible groups (Flanagan et al., 2020; Noy & Yonson, 2018). These components have been measured using a range of indicators. The analysis of the overall vulnerability of the Southeast Asian (SEA) area reveals that Myanmar is particularly prone to adverse effects during disasters, with Nepal and Bangladesh also recognised as similarly sensitive. Maldives is considered to be the nation with the lowest vulnerability.

Table 1: Vulnerability Profile of SEA Region

COUNTRY	ISO3	Socio-Economic Vulnerability	Other Vulnerable Groups	VULNERABILITY	Profile
Bangladesh	BGD	3.9	5.6	4.8	High
Bhutan	BTN	4.9	0.9	3.1	Low
India	IND	4.0	5.1	4.6	Medium
Indonesia	IDN	2.4	3.0	2.7	Low
Korea DPR	PRK	5.0	2.9	4.0	Medium
Maldives	MDV	2.6	0.7	1.7	Very low
Myanmar	MMR	5.5	6.0	5.8	High
Nepal	NPL	4.1	5.9	5.1	High
Sri Lanka	LKA	2.7	5.0	3.9	Medium
Thailand	THA	2.0	4.0	3.1	Low
Timor-Leste	TLS	4.7	4.5	4.6	Medium

2.5 Coping Capacity Profile

The INFORM index breaks down coping capacity into three main components. Firstly, Institutional Capacity, and Infrastructure. The notion of institutional capacity pertains to the aptitude of an organization or institution to proficiently execute its activities and obligations. The subject matter comprises two primary components, namely the notion of governance and Disaster Risk Reduction (DRR). Governance encompasses various dimensions, including the effectiveness of governmental institutions, as well as endeavors aimed at addressing and mitigating corruption.

Infrastructure encompasses a wide range of physical and organizational structures that are essential for the functioning of societies and economies. The topic of discussion pertains to physical infrastructure. This study centers on the condition and availability of essential infrastructural systems, including road networks, water supply, and sanitation facilities.

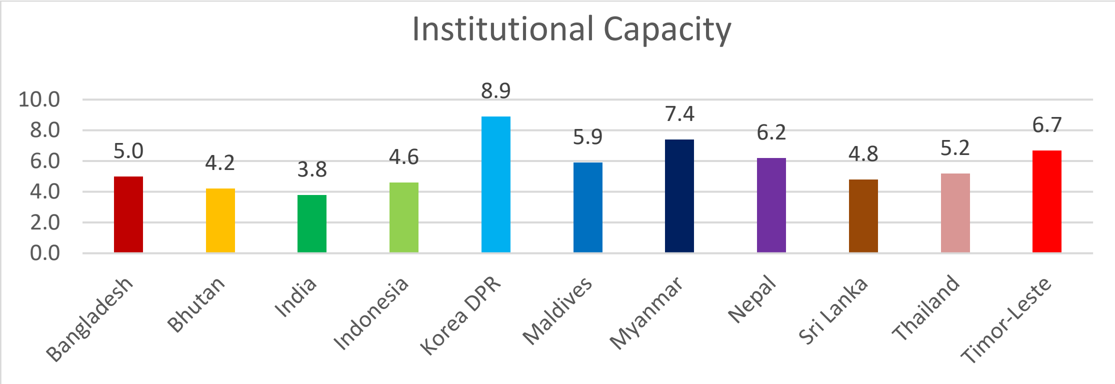


Figure 7: Institutional Capacity

The evaluation of health services encompasses an assessment of the quality and accessibility of healthcare facilities, taking into consideration factors such as physician density, health spending per capita, and the rate of one-year-old inoculation against measles. Communication serves as a metric for assessing the strength and extent of essential services, such as electricity, internet connectivity, and adult literacy rates.

The aforementioned component has been enhanced in the 2021 INFORM index methodology to incorporate additional public services related to institutional capacity and utility services. This includes the extent of utility services such as water, electricity, and sanitation systems under the domain of infrastructure and services.

The concept of coping capacity can be delineated using two distinct terms: a) The capacity of individuals to cope with challenges and adversities. b) The capacity of institutions to effectively respond to and manage various situations and demands.

The assessment of risk in the Southeast Asia and the Pacific (SEAR) region, taking into account vulnerability and coping capability, is crucial for the development of comprehensive action plans aimed at effectively managing potential hazards that have the potential to escalate into major disasters within the SEAR region.

Figure 7 explains that Korea DPR has maximum institutional capacity to deal with disasters as system is in place without much corruption and also is following frameworks properly. Followed by DPR Korea is Myanmar and then Timor Leste & Nepal. Maldives, Thailand, Bangladesh has average capacity.

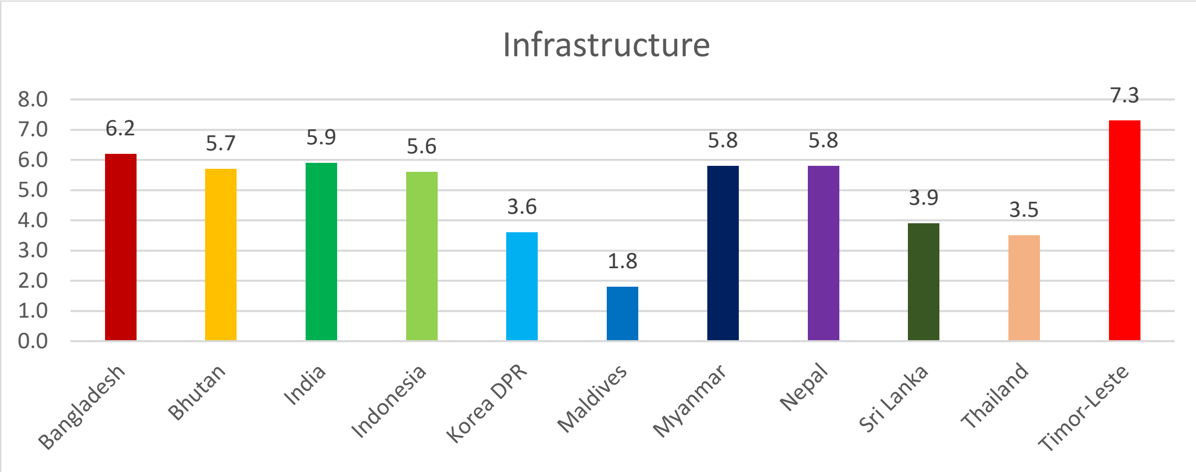


Figure 8: Infrastructure Analysis

Figure 8 shows that Timor Leste has good infrastructure to deal with disasters followed by Bangladesh, India, Myanmar & Nepal, Bhutan and Indonesia. Maldives, Korea DPR and Sri Lanka and Thailand have to improve a lot in infrastructure.

2.5.1 Coping Capacity Index Inference

The provided data offers a comprehensive assessment of countries in terms of their disaster risk reduction (DRR), governance, institutional structures, communication capabilities, physical connectivity, healthcare access, infrastructure, lack of coping capacity, and an overall profile determining their readiness and resilience towards potential disasters. Taking geo-mean of Inform Institutional and Inform Infrastructure and indexing within range 0 to 10 gives component of coping capacity

Several nations, such as Bangladesh, Bhutan, India, Indonesia, and Timor-Leste, have moderate to high levels of performance in governance and institutional measures, suggesting diverse degrees of efficacy in their formal systems for disaster management. The Democratic People's Republic of Korea (DPRK), often known as North Korea, provides data (referred to as X) in the field of disaster risk reduction (DRR). However, it is noteworthy that North Korea achieves the highest score in governance and institutional measures. Despite this, its overall profile is categorized as 'High', indicating a potential deficiency in the requisite coping mechanisms for managing catastrophes. As indicated by figure 11, Timor Leste have highest index for health care followed by Indonesia. Other countries also have good health care facilities. However, Korea DPR and Maldives has lowest health care index.

The countries of Maldives, Sri Lanka, and Thailand exhibit limited performance in terms of communication and physical connectivity, suggesting potential difficulties in the distribution of information and the ability to reach isolated regions in times of crisis. The participants' coping capacity profiles were assessed as being of low level. Myanmar, Nepal, and Timor-Leste have higher ratings across all categories, indicating possible vulnerabilities. Their overall profiles are classified as 'High', suggesting that these countries may encounter considerable hurdles in the event of disasters.

Table 2: Coping Capacity Index

COUNTRY	ISO3	DRR	Governance	INFORM Institutional	Communication	Physical Connectivity	Access to health care Index	INFORM Infrastructure	Lack of coping capacity	PROFILE
Bangladesh	BGD	3	7	5	6.4	5	7.2	6.2	5.6	Medium
Bhutan	BTN	4.5	3.9	4.2	5.5	5.1	6.4	5.7	5.0	Medium
India	IND	1.8	5.7	3.8	5.4	5.2	7.2	5.9	4.9	Medium
Indonesia	IDN	3.3	5.9	4.6	3.3	5.3	8.1	5.6	5.1	Medium
Korea DPR	PRK	X	8.9	8.9	6.7	3.1	1	3.6	7.0	High
Maldives	MDV	5.8	6	5.9	1.3	0.1	4.1	1.8	4.1	Low
Myanmar	MMR	7.1	7.6	7.4	5.1	5.1	7.3	5.8	6.7	High
Nepal	NPL	5.4	7	6.2	5.7	5.4	6.3	5.8	6.0	High
Sri Lanka	LKA	3.6	6	4.8	3.6	2.4	5.8	3.9	4.4	Low
Thailand	THA	4.7	5.6	5.2	2.7	2.3	5.6	3.5	4.4	Low
Timor-Leste	TLS	6.3	7	6.7	6.5	6.8	8.7	7.3	7.0	High

Table 2 demonstrates that the coping capacity of DPR Korea, Myanmar, Nepal, and Timor Leste is minimal, categorising their risk as high. Myanmar, Bangladesh, Bhutan, India, and Nepal are all at elevated risk due to insufficient coping ability, but slightly behind these countries. India and Indonesia, despite their large populations and geographical diversity, exhibit a 'Medium' profile, indicating a reasonably balanced capacity to effectively handle and address natural disasters.

3 Result and Discussion

3.1.1 Earthquake Hazard Map –SEA Region

The Seismotectonic History of the Region: The Southeast Asia region is characterized by varying levels of seismic hazard (Bhatia et al., n.d.; Zhang et al., n.d.). The Indonesian and Philippine archipelagos are situated in areas with high seismic hazard, indicating a greater likelihood of experiencing significant seismic activity (Irsyam et al., 2008, 2020; Watkinson & Hall, 2017). On the other hand, the Malaysian peninsula is located in an area with moderately low seismic hazard, suggesting a relatively lower probability of encountering major seismic events. The Indonesian archipelago is characterised by significant volcanic and seismic activity resulting from the subduction of the India and Australia tectonic plates beneath the Sunda and Burma tectonic plates. According to Petersen et al. (2007), seismic events occurring within the subduction zones of the Indian and Australian plates can reach considerable depths, spanning hundreds of kilometers. On December 26th, 2004, a highly destructive mega thrust earthquake with a magnitude of 9.1 took place, characterized by thrust-faulting along the boundary between the Indian plate and the Burmese plate. The tsunami that ensued led to substantial socio-economic repercussions in multiple nations, including Indonesia, Thailand, India, Myanmar, Sri Lanka, and Maldives (Amaratunga & Haigh, 2011; Haigh et al., 2018; Petersen et al., 2007). Earthquakes occur along edge of oceanic plates, continental plates and along fault lines. The map is prepared on the basis of data fetched from Global Risk Data Platform.

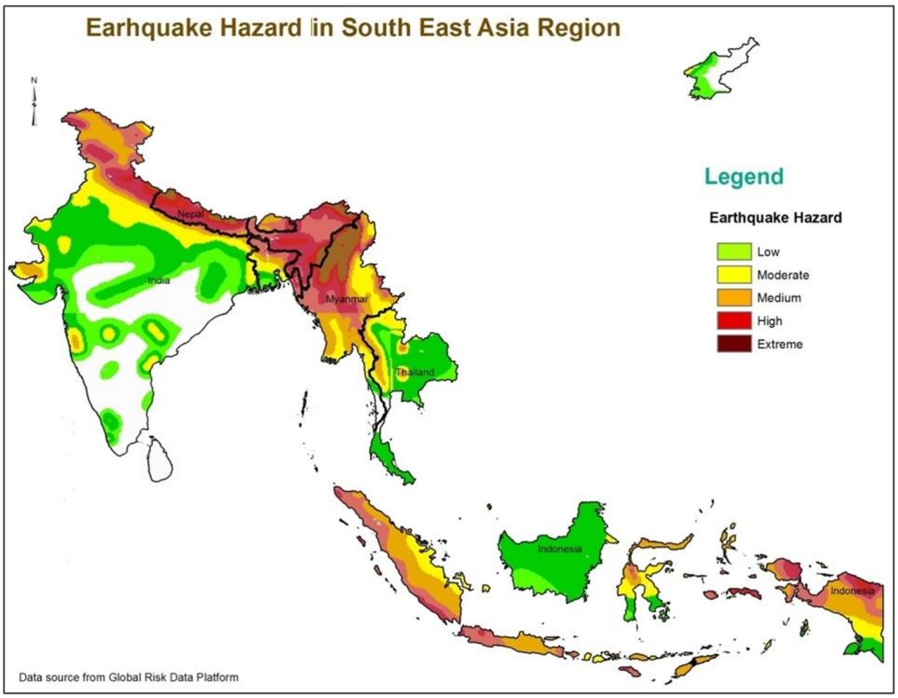


Figure 9: Earthquake Hazard Map

The Figure 9 displays Earthquake Hazard Map indicates that regions of Nepal, India, Myanmar, and Indonesia are at the highest risk of earthquakes due to their location in active seismic zones.

DPR Korea, Thailand, Sri Lanka, and the Maldives exhibit a low to moderate risk of earthquakes.

3.1.2 Exposure to Earthquake - Inform Index

In the inform index, the measurement of the hazard and exposure dimensions focuses solely on intensity levels ranging from VI to VIII. This is due to the higher levels of devastation associated with these intensities.

Table 3: Index for Earthquake Hazard

COUNTRY	Iso3	Physical exposure to earthquake MMI VI (absolute)	Physical exposure to earthquake MMI VIII (absolute)	Physical exposure to earthquake (absolute)	Physical exposure to earthquake MMI VI (relative)	Physical exposure to earthquake MMI VIII (relative)	Physical exposure to earthquake (relative)	Physical exposure to earthquake
Bangladesh	BGD	10.0	10.0	10.0	8.0	1.2	5.6	**8.6**
Bhutan	BTN	5.4	4.8	5.1	10.0	3.9	8.3	**7.0**
India	IND	10.0	10.0	10.0	2.9	0.5	1.8	**7.9**
Indonesia	IDN	10.0	9.4	9.7	9.1	0.3	6.4	**8.5**
Korea DPR	PRK	0.1	0.1	0.1	0.0	0.0	0.0	**0.1**
Maldives	MDV	0.1	0.1	0.1	0.0	0.0	0.0	**0.1**
Myanmar	MMR	10.0	10.0	10.0	9.9	4.3	8.2	**9.3**
Nepal	NPL	9.5	10.0	9.8	10.0	10.0	10.0	**9.9**
Sri Lanka	LKA	0.1	0.1	0.1	0.0	0.0	0.0	**0.1**
Thailand	THA	8.1	0.1	5.4	1.3	0.0	0.7	**3.4**

Timor-Leste	TLS	6.0	0.1	3.6	10.0	0.0	7.6	**6.0**
	MAX	**5.0**	**4.0**		**0.20%**	**0.10%**		
	MIN	**1.0**	**1.0**		**0.00%**	**0.00%**		

The given table 3 showcases the physical exposure to earthquake risks across different countries in terms of both absolute and relative measures. MMI VI and MMI VIII refer to the Modified Mercalli Intensity scale levels that describe the intensity of an earthquake. Higher values on this scale imply stronger intensities, with potential for more destruction.

Table 13 shows the purpose of risk calculation. The final values for danger and exposure are indicated in red, following the calculation of the geometric mean of absolute and relative values and constraining it within the range of 0-10. The above table 13 depicts that Bangladesh, India, Indonesia, and Myanmar consistently have the greatest levels of absolute exposure (10.0) in terms of MMI VI, MMI VIII, and overall seismic exposure. Nepal exhibits a strong correlation with a magnitude of 9.5 on the Modified Mercalli Intensity (MMI) scale for level VI, and a magnitude of 10.0 for level VIII. In terms of relative exposure, Bhutan, Indonesia, Myanmar, Nepal, and Timor-Leste exhibit significant levels of exposure across the scales listed, with scores that are close to or at 10.0. This suggests that a notable fraction of their populace or territorial expanse is susceptible to hazards in relation to their overall population or geographical extent. As far limited exposure is concerned Korea DPR, Maldives, and Sri Lanka regularly exhibit limited exposure in terms of both absolute and relative measurements, suggesting that these countries face minor hazards associated with earthquakes. The country of Thailand demonstrates a notable pattern in terms of seismic exposure, characterized by a significant level of absolute exposure at Modified Mercalli Intensity (MMI) VI (8.1), while exhibiting an exceptionally low level of exposure at MMI VIII (0.1).

In essence, countries like Bangladesh, India, Indonesia, Myanmar, and Nepal face significant earthquake risks both in terms of the absolute number of people or areas exposed and in terms relative to their total population or landmass. Counter to this, countries like Korea DPR, Maldives, and Sri Lanka have minimal risks associated with earthquakes.

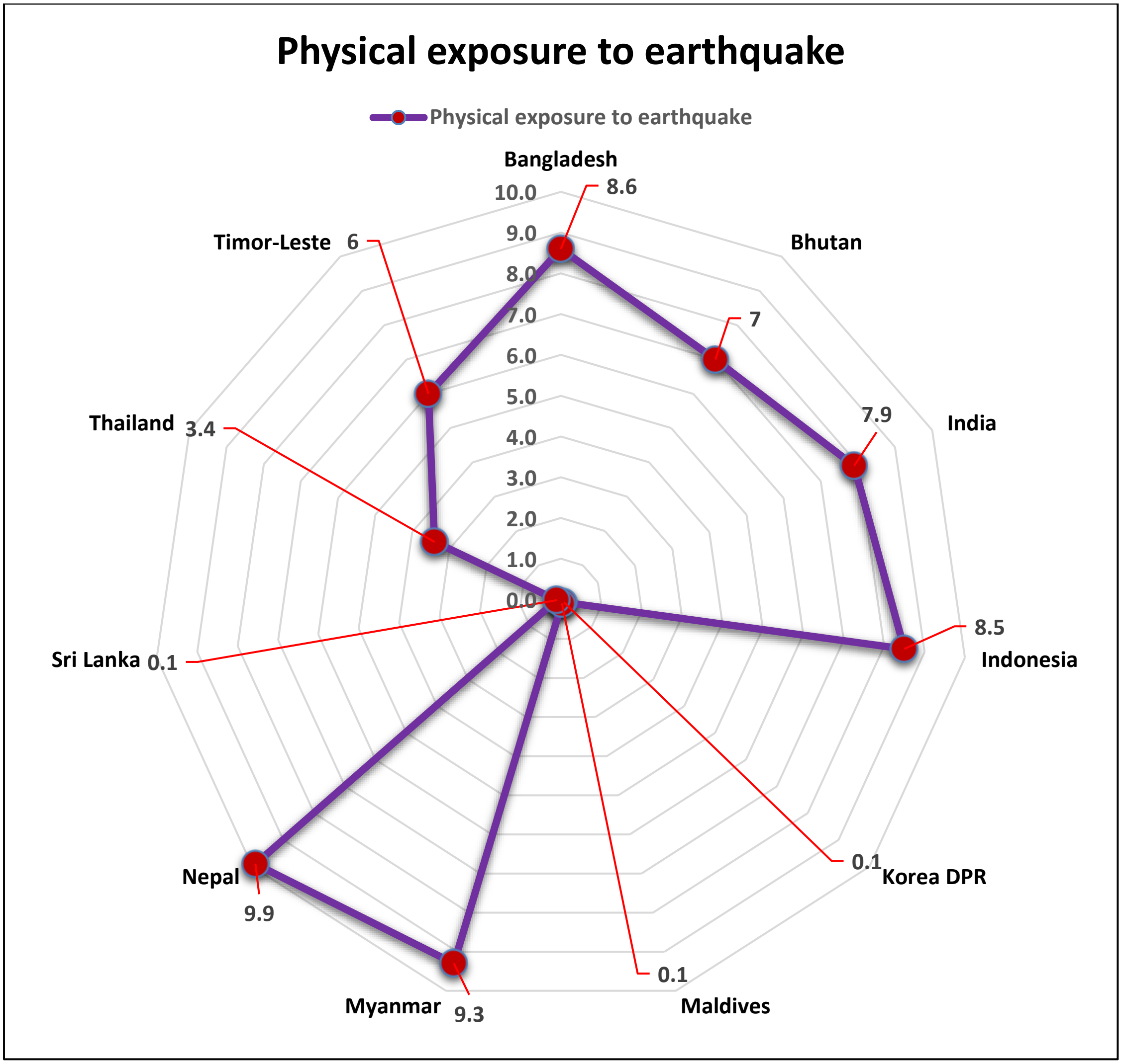


Figure 10: Analysis of Exposure to Earthquake

The graph in Figure 10, explains that exposure index to hazard is highest for Nepal followed by Myanmar and Bangladesh. Least affected country is Korea DPR, Sri Lanka and Maldives. Nepal, because to its geographical location in the Himalayan region, experiences the highest level of earthquake exposure. This is followed by Myanmar, Bangladesh, Indonesia, and India. The unexpected decline of North Korea can be attributed to a dearth of information and data accessibility. Sri Lanka, the Maldives, and Thailand are considered to have a relatively low level of exposure to earthquake danger.

3.2 Overall Earthquake Risk in Southeast Asia

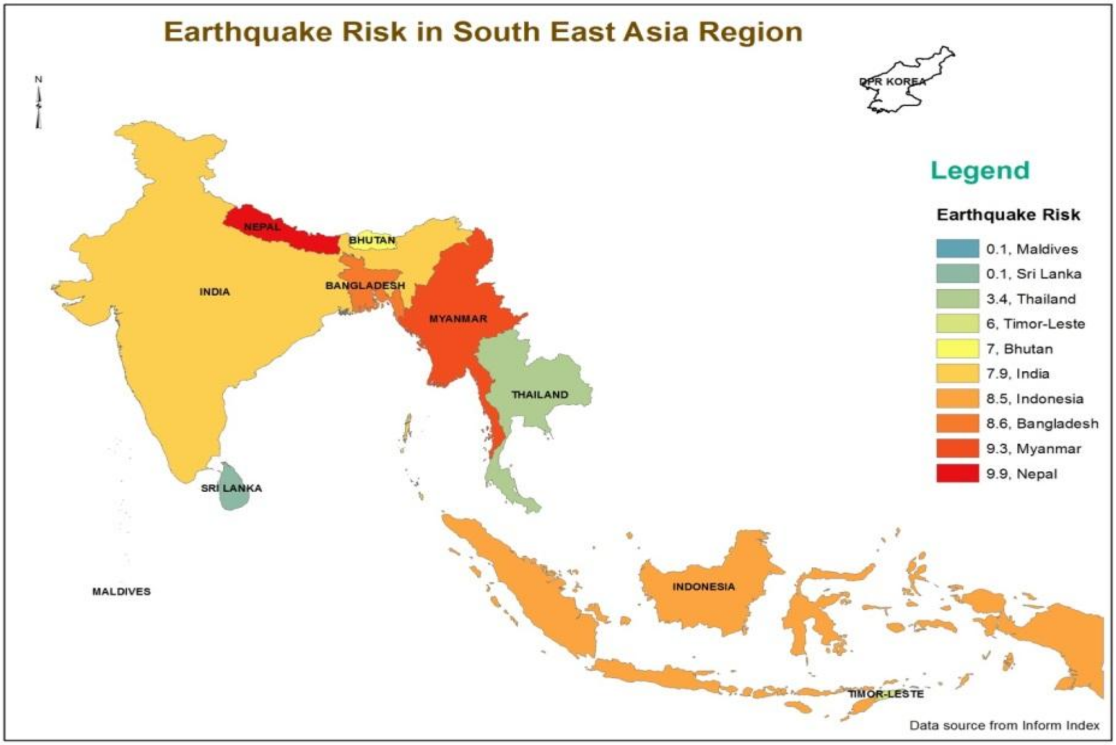
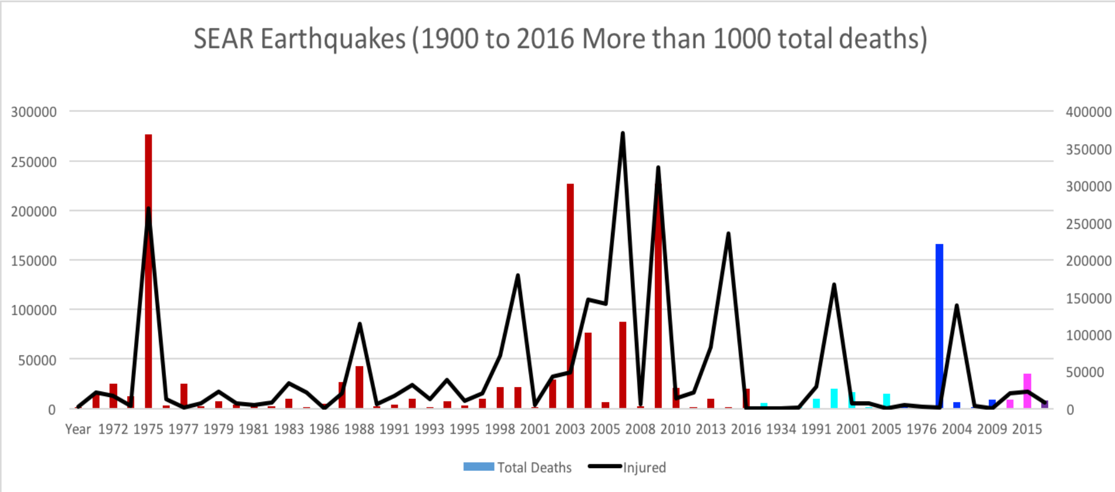


Figure 11: Earthquake Risk in Southeast Asia

The map reflecting the index shows that Nepal, Myanmar, and Bangladesh fall under very high to high risk area anticipating all the indicators, variables for lack of hazards, vulnerability, and lack of coping capacity, which is reflected in below table of total mortality and morbidity. Timor-Leste, Bhutan, and India remains under moderate risk, while Sri Lanka, and Maldives has the least overall risk in south east Asian countries, as reflected in Figure 101.

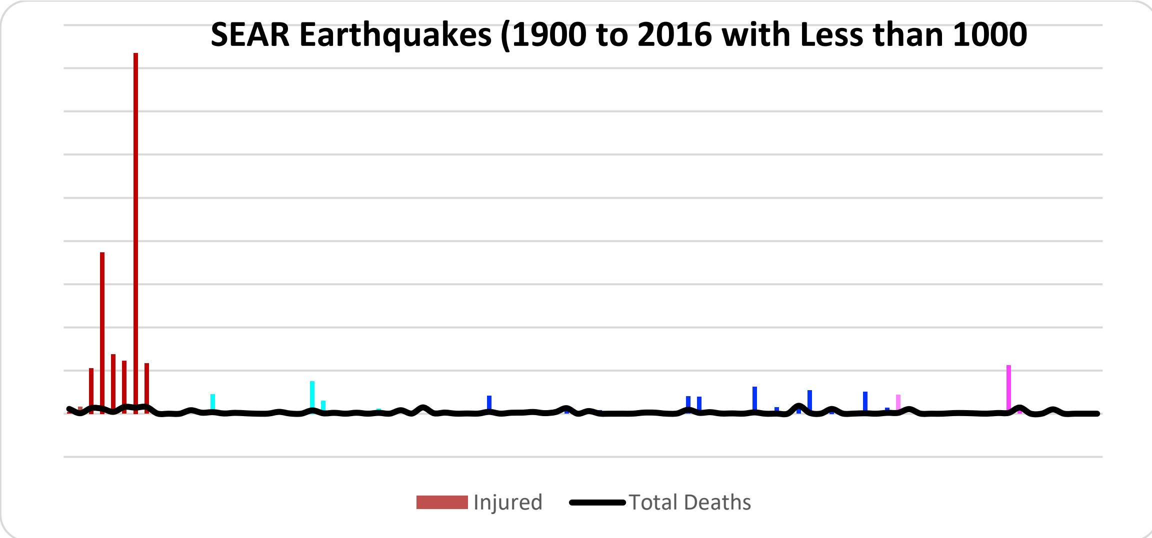
3.2.1 Analysis of Losses



	Bangladesh		India		Myanmar		Thailand
	Bhutan		Indonesia		Nepal		Timor
	DPR Korea		Maldives		Sri Lanka		

Figure 12: Losses due to Earthquake (>1000 deaths)

Figure 12 illustrates the mortality resulting from earthquakes in the Southeast Asia Region (SEAR) countries, encompassing the period from 1900 to 2016. The data reveals that the number of fatalities and injuries caused by earthquakes exceeded 1000 individuals throughout this time frame. The graph presented above illustrates the number of fatalities resulting from earthquakes in Bangladesh, India, Sri Lanka, Nepal, and Indonesia, which exceeds 1000 individuals. In 2004, Indonesia experienced a devastating earthquake with a magnitude of 9.1-9.3, resulting in a significant loss of life. The recorded death toll reached a peak of 230,000-280,000 individuals. This catastrophic event was triggered by the Tsunami Basin.



	Bangladesh		India		Myanmar		Thailand
	Bhutan		Indonesia		Nepal		Timor
	DPR Korea		Maldives		Sri Lanka		

Figure 13: Loss due to Earthquake (< 1000 deaths)

Figure 13 illustrates the mortality resulting from earthquakes during the time span of 1900 to 2016. The data presented in this figure encompasses a century-long period, documenting the occurrence of less than 1000 deaths and injuries across various countries. These casualties can be attributed to the fragility of the affected regions. The seismic events occurring in the years 2001 and 2015 have exhibited a significant level of effect. The degree of impact varies across countries within the region, contingent upon factors such as hazard risk, vulnerability, readiness, and coping capacity.

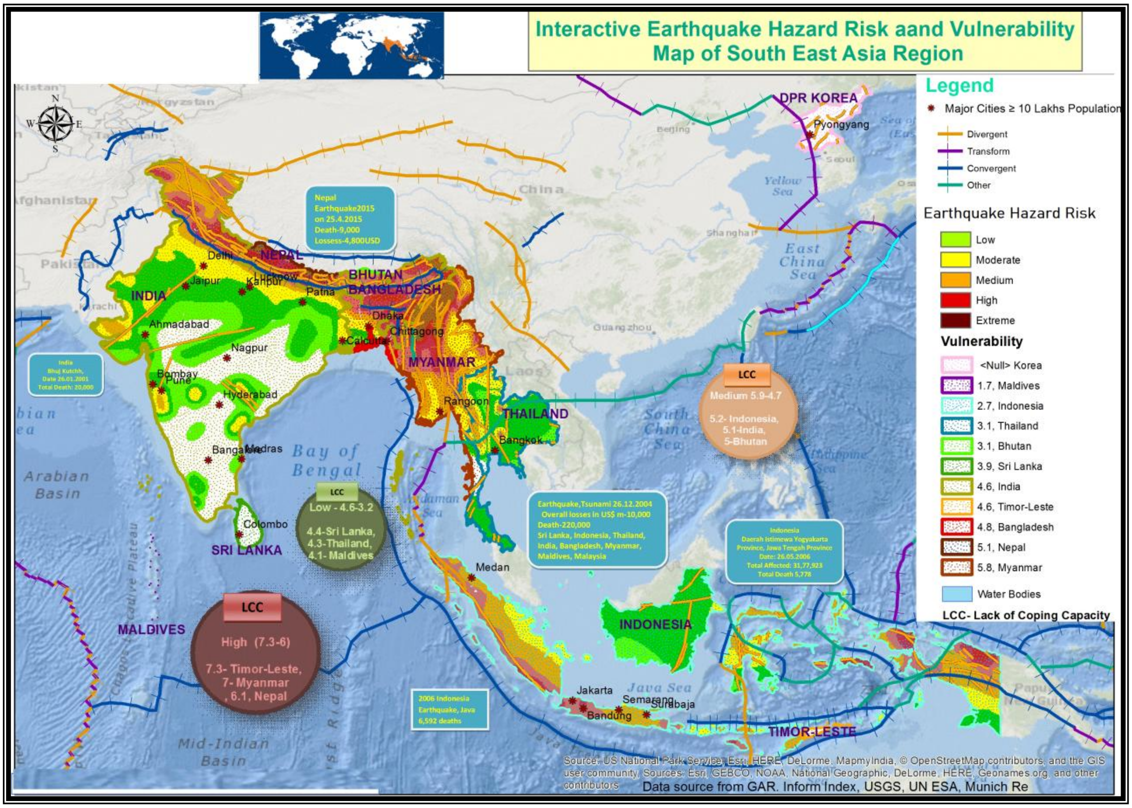


Figure 14: Interactive Earthquake hazard Risk and Vulnerability Map of South East Asia Region

In order to gain a comprehensive understanding of the situation, the provided figure aims to provide an overview of the various complications present in the Southeast Asian region. Its purpose is to acknowledge the interplay between vulnerability, LCC, and the earthquake hazards overall risk, as shown in Figure 14. Additionally, it highlights the presence of significant fault lines and densely populated cities within the region.

4 Conclusion

Severe seismic events predominantly result in fatalities and injuries due to the collapse of structures, exacerbated by suboptimal urban planning and infrastructure development. An analysis reveals that among the eleven surveyed nations, DPR Korea, Maldives, and Sri Lanka manifest the lowest seismic risks. In contrast, eight countries within the SEA region are discernibly prone to high earthquake hazards. The overarching patterns in vulnerability and resilience capacities underscore the imperative for substantial strategic interventions and investments to enhance community well-being.

To bolster the resilience of the Southeast Asian (SEA) region against seismic disasters, several tailored recommendations might be suggested. First and foremost, it is imperative to establish a formalized procedure that guarantees periodic structural safety audits for critical structures and edifices. Additionally, it is imperative to prioritize the enhancement and seismic retrofitting of specific lifeline structures. The importance of seismic micro-zonation cannot be overstated, particularly in areas that have been identified as being susceptible to seismic hazards. Simultaneously, it is imperative to reassess land use and urban planning rules in order to incorporate earthquake hazard zoning. It is very important to keep strict building codes in place to make sure that structures are stable. This means that they must be strictly enforced and followed. Also, it is crucial to make the health system's ability to grow a top priority. This goal can be reached by using two methods: training more health workers in crisis management and increasing the number of health workers who are already good at it. Setting up specialised resource centres is very important for making sure that help is always available during catastrophes. It is also clear that regional emergency operations need to be set up. This project would not only make earthquake safety rules stronger, but it would also make sure that people respond quickly in times of crisis. Finally, it is vitally important to look closely at the infrastructure in each Southeast Asian country to make sure that each sector has made progress.

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