

Disaster Vulnerability Assessment of Shillong, Meghalaya

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Abstract

The Indian Himalayan Region (IHR) is highly vulnerable to natural disasters like earthquakes, floods and landslides due to its geo-environmental settings. Urbanisation is exerting additional environmental stress and amplifies the impact of natural disasters. Besides poor legal enforcement of regulations, inadequate infrastructural services also increase the vulnerability of socially and economically marginalised populations. The IHR is also expected to experience severe impacts of climate change in the future. Therefore, the need of the hour is to assess and understand the status of vulnerability of Himalayan cities to further devise strategies and plans to make them disaster resilient. A Rapid Vulnerability Assessment (RVA) framework, based on parameters such as topography, disaster trends, climate scenarios and projections, the status of infrastructure and governance, has been used to assess disaster vulnerability of the Indian Himalayan Region (IHR) city Shillong, Meghalaya. The analysis reveals that the city is prone to various hazards such as earthquakes, landslides, flash floods and thunderstorms/lightning and most of these are climate induced hazards. The paper also provides certain recommendations for enhancing the disaster resilience of the city, in terms of development and provision of the basic physical and socio-economic infrastructure for the vulnerable population, while adapting to indigenous hazard management mechanisms, strengthening of the governance and administrative structure of the city.

Keywords: Indian Himalayan Region, Natural Disasters, Urbanisation, Vulnerability Assessment, Disaster Resilience, Adaptation, Shillong

Introduction

India is geographically located in the high disaster-prone region and has been continuously impacted by natural disasters like floods, cyclones, landslides, earthquakes, heatwaves and Tsunami. Out of 36 states and union territories (28 States and 8 Union Territories) in the country, 27 of them are disaster prone (NIDM). Over the past thirty years, earthquakes have accounted for 34.8 per cent of total deaths by natural disasters. During 1980-2010, India has experienced nearly 431 natural disasters killing around 0.00014 billion people and affecting around 150 million people, with an estimated economic loss of USD 48.06 billion (EM-DAT, 2019; Parida Y, 2020).

Global Climate Risk Index report (2019) had stated India as the 14th most vulnerable country in the world due to extreme weather-related events, with around 2,736 lives lost in 2017 due to disasters. The Global Climate Risk Index report 2020 (Bandhopadhyay K, 2019), ranks India 5th in 2018 in the global vulnerability ladder, with a highest recorded number of fatalities due to climate change and the second-highest monetary losses from its impact in 2018. India's high rank is due to severe rainfalls, followed by massive flooding and landslides that killed over 1000 people.

Indian Himalayan region covers 16 per cent of India's total geographical area, spread over 12 states (ENVIS, 2018). Himalayan Region (IHR) is considered to be vulnerable to a variety of natural disasters like earthquakes, floods, landslides and forest fires etc. According to the United Nations-affiliated organization and Planning Commission, the Himalayan region, on an average is hit by 76 disasters, killing 36,000 people and affecting 178 million people every year (Hindustan Times, 2013). Nepal-based International Centre for Integrated Mountain Development claimed that India's Himalayan region was hit by 532 natural disasters between 1990-2012 (Khadka, 2020).

Box 1: The Disaster Management Act- 2005

“Disaster” means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man-made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area.

Source: National Disaster Management Plan, NDMA Gol, 2016

Floods, earthquakes, cyclones and hailstorms are the most frequently occurring hazards in India and 27 out of 35 states and union territories are prone to these types of hazards. Over the past thirty years, earthquakes alone have accounted for 34.8 per cent of total deaths by natural disasters. During 1980-2010, India experienced nearly 431 natural disasters killing around 140,000 people and affecting around 15 million people, with an economic loss of US\$ 48.06 billion (EM-DAT, 2019). With growing urbanisation and increasing occurrences of small- and large-scale disasters in urban areas, years of development effort and infrastructure are continually being destroyed and eroded (Sanderson, 2000).

Literature Review

The Indian Himalayan region covers 16 per cent of India's total geographical area, spread over 12 states (ENVIS, 2018). The Union Ministry of Environment and Forests, 2010, identified the Himalayan

region as one of the four most vulnerable areas to natural disasters such as earthquakes, floods, landslides and forest fires. On an average, IHR is hit by 76 disasters every year, killing 36,000 people and affecting 178 million people (United Nations-affiliated organisation, 2013). The Himalayan region recorded nearly 127 landslides between 2009-2018 (Khadka, 2021).

The north-eastern (NE) region in India, particularly, is more vulnerable to natural disasters, due to its fragile geo-environmental settings and economic under-development. Rapid growth is currently taking place in the environmentally unbothered/ undisturbed/ non-urbanised region of the Himalayas. From a completely economic standpoint this may seem ideal, at least in the short run; however, the haphazard buildings made to adapt to such rapid changes have resulted in environmental degradation (Anbalagan, 1993). The increasing levels of urbanisation, if not handled with caution, will be extremely detrimental to the climate and people of the Himalayas (Walker, 2011). A high degree of vulnerability to these disasters will increasingly make the region environmentally insecure in the future unless pragmatic interventions are made immediately.

Box 2: Disaster Resilient City

A natural hazard turns into disaster due structural and managerial flaws as well as the violation of natural and man-made laws before the hazard strikes. A disaster resilient city has the capacity to deal with such disasters—it can cope with or withstand perturbation up to a moderate degree.

Source: Parikh. J., 2014, Retrieved from <https://irade.org/Disasterper cent20Resilientper cent20Cities.pdf>, as accessed on June 29, 2021

City level resilience can be built through a strong infrastructure, able governance and good socio-economic conditions. Climate change adds yet another layer of stress to those of environmental degradation and rapid unplanned urban growth, further reducing communities' abilities to cope with even the existing levels of weather hazards (UNISDR, WHO, 2008). Climate change increases the risk of disaster— by increasing the vulnerability of communities to natural hazards, particularly through ecosystem degradation and reduction in water and food availability. It also causes subsequent livelihood changes.

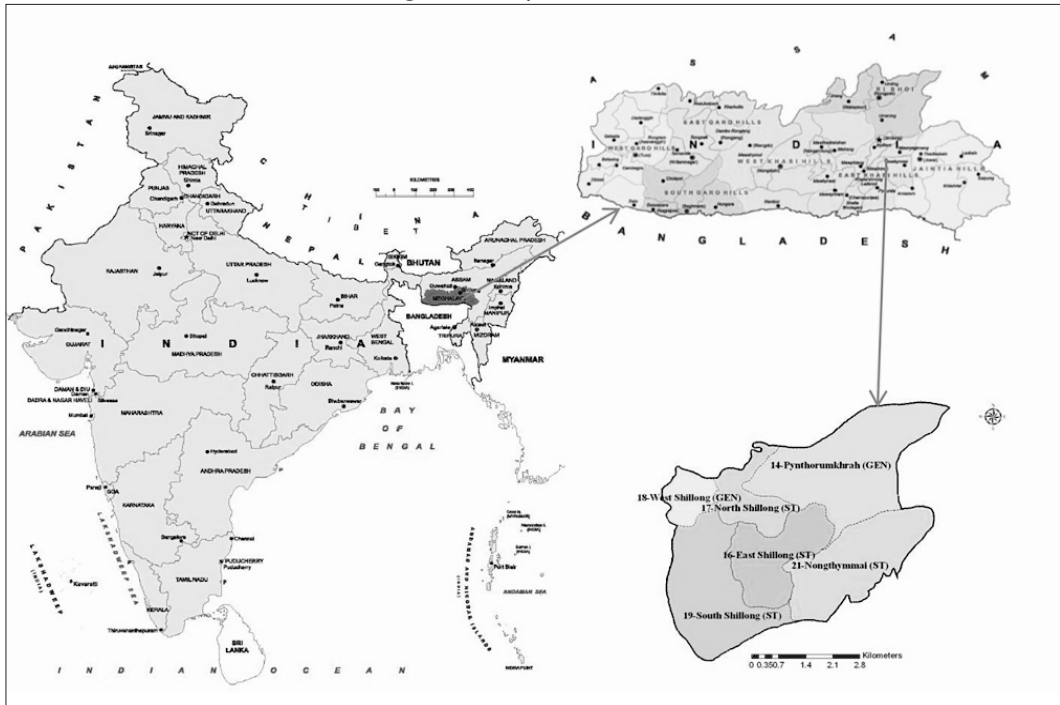
This study, supported by the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India (GoI), under National Mission on Himalayan Studies (NMHS) to carryout studies in the Indian Himalayan Region with a view to develop their disaster resilience plans by highlighting their exposure to potential hazards using advanced technologies like satellite remote sensing and Geographical Information Systems (GIS). This paper presents the results of Rapid Disaster Vulnerability Assessment of Shillong city, Meghalaya with a view to highlight the city's exposure to potential hazards.

Study Area- Shillong, Meghalaya

Shillong, the capital city of Meghalaya, is situated at an altitude of 4,908 ft above mean sea level. It lies in the centre of the Shillong plateau surrounded by hills. The humid subtropical climate of Shillong is characterised by moderately warm wet summers and cool dry winters. The average maximum and minimum temperature is around 20°C and 12°C respectively. The city experiences a prolonged

rainy season with intermittent rains throughout the year. Two-thirds of the rainfall occurs in the months of June to September, from the south-west monsoon with relative humidity being highest during the rainy season (above 80 per cent). Shillong Urban Agglomeration covers an area of 70.4 square kilometres. It includes Shillong Municipality, the Cantonment, and the townships of Mawlai, Nongthymmai, Madanrtng, Pynthorumkhrah, Nongmynsong (Tariang, 2011). Figures 1 and 2 show Shillong city maps.

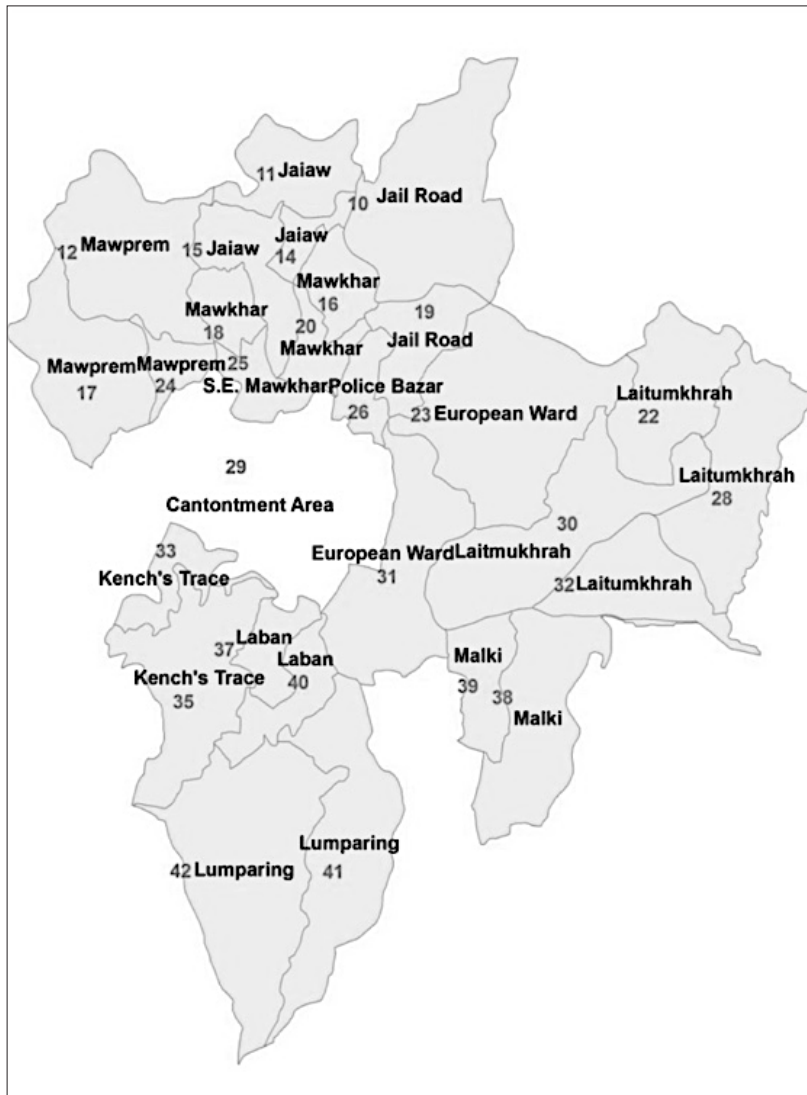
Figure 1: Study Area Location



Source: Shillong Disaster Resilience Action Plan, IRADe, 2020-21

Shillong is also the most urbanised and largest city in the hill state of Meghalaya. The population of the city is 143,229 (Census, 2011). The population growth rate over the last decade has been 7.79 per cent (Census, 2001: population 132,867). The city has witnessed unprecedented population growth in recent years largely due to a high fertility rate coupled with increased migration from neighbouring states of India.

Figure 2: Shillong City- Ward Level Map



Source: City Development Plan, Shillong, 2018

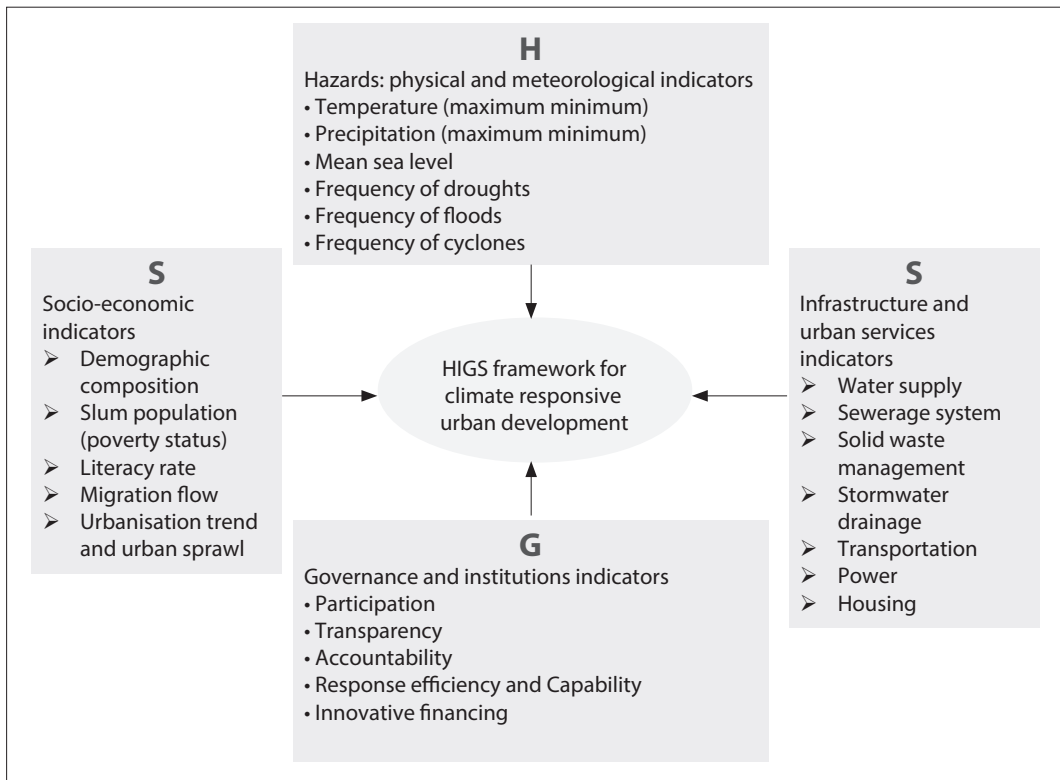
The city of Shillong is highly vulnerable to earthquakes as it falls under the high-risk seismic Zone V. Apart from earthquakes, Shillong is also vulnerable to natural hazards such as flash floods, landslides, extreme winds and thunderstorms.

Data and Methodology

To understand and analyse the rapid vulnerability and climate-resilient measures necessary in India's urban centres, a Rapid Hazard and Vulnerability Assessment framework (RHVA) was designed by IRADe

in Asian Cities Climate Resilience, Working Paper Series 8, IIED (Jyoti Parikh, 2014). The framework was developed based on four themes “Hazards-Infrastructure-Governance-Socio-Economic characteristics (HIGS)”. The goal was to systematically understand urban issues that shape climate-resilient urban development and thence help shape policies and projects developed by cities to address these risks. The framework was designed to determine the city’s characteristics such as location, economic and geographical parameters to further determine the exposure to hazards. City-level disaster risks can be analysed using the HIGS framework that integrates information on physical and meteorological hazards, analyses infrastructure and urban services, governance variables, and finally socio-economic and demographic indicators (Figure 3). This RVA (Rapid Vulnerability Assessment) framework provides a customisable approach for cities to analyse their own vulnerabilities to understand the potential areas of corrective action as well as enabling comparison across cities. It further identifies impacts, which are of concern across multiple cities, and are city-specific. Such a nuanced analysis is needed to better inform national, state and local policy making on urban development and management. What is particularly valuable is that the rapid assessment methodology can spur autonomous action by enabling cities to assess their vulnerabilities using the HIGS framework and to prioritise response strategies.

Figure 3: HIGS Framework and Detailed List of Variables



Source: Asian Cities Resilience, IIED & IRADe <https://irade.org/10657IIED.pdf>, as accessed on June 29, 2021

The RVA (HIGS) framework was further improvised and first applied by IRADe on 20 Indian cities for assessing their vulnerability to natural hazards. Later in 2012-2014 IRADe further evolved a HIGS framework and conducted a study on disaster resilience across 10 cities in India, viz. Pune, Ahmedabad, Bhopal, Vishakhapatnam, Hyderabad, Bhubaneswar, Shillong, Guwahati, Dehradun and Srinagar (J. Parikh, 2015). The holistic framework HIGS (J. Parikh, 2015). was further improved and extended for assessing disaster resilience in 10 cities (Rohit Magotra, 2019) by incorporating parameters that give local/regional diversification, flexibility and interdependency (flow of information with clarity) to be customised for use in other regions/cities. The framework is further made more dynamic by adding more climatic parameters (temperature, precipitation, climatic scenarios and projections, etc.) and evaluating their status. The methodology in this study revolves around collecting secondary information from the cities and analyzing them with respect to:

- a. Exposure and vulnerability
- b. Evaluation of existing critical infrastructure and basic urban services
- c. Resilience (response and recovery systems) and evaluation of city management and governance.

Data for Shillong has been collected through primary and secondary sources, including stakeholder consultations with ULBs (urban local bodies) and related agencies. Also, historic weather data, hazard timelines and exposure to various hazards were compiled and collated with abnormal natural events to evaluate the vulnerable profile of the region. Various parameters have been analysed to assess each of the four aspects (Hazard, Infrastructure, Governance and Socio-Economic conditions) of the framework which include:

- a. **Hazards and extreme events:** Exposure to geophysical variables; past history of hazards, their frequency of occurrence and magnitude of impact. Climate variables observed and projected.
- b. **Infrastructure status:** Water supply, waste management, storm-water drainage system, power and transport infrastructure, status of the building and services infrastructure, maintenance, coverage and access to the basic infrastructure.
- c. **Governance:** The institutional framework of the city management, urban administration, public health, recovery system and evaluation of city management in the context of disaster proneness, financial status/independence of the ULBs, and efficiency in delivering the basic services. Smart initiatives like E-governance, ICT (Information and Communication Technology)
- d. **Socio-economic conditions:** Population and urbanisation trends, urban population density and slum population.

Interconnection of different variables is important to bring forth the priorities of disaster resilience towards which the cities must act fast and integrate these into their developmental activities.

The Urban Vulnerability Assessment Framework was used to assess the urban climate vulnerability of the Shillong and to bring forth the areas of adaptation which the city should prioritise for improving its resilience and integrate with its developmental initiatives.

Analysis and Discussion

Disaster Vulnerability of Shillong City

Shillong city is prone to various hazards because of its geo-ecological fragility, the eastern Himalayan landscape, its trans-boundary river basins and its inherent socio-economic instabilities. The city is vulnerable to both natural hazards such as earthquakes, landslides, heavy rainfall, floods, extreme wind and thunderstorms, and also to rapid growth of urbanisation and improper and uncontrolled construction. Table 1 shows the history of disasters in Shillong city (J. Parikh, 2015).

Table 1: History of Disasters in Shillong City and their Impact

Type of Hazards	Year of Occurrence	Frequency	Impact on			
			Population	Life	Livelihood	Livestock
Earthquake	1897, 1897, 1923, 1930, 1932, 1945, 1950, 1951	8	✓	✓	✓	✓
Extreme winds/ Thunderstorms	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013	13	✓	No data available	✓	✓
Flash Floods	1999, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013	13	✓	✓	✓	✓
Landslides	1999, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013	13	✓	✓	✓	✓
Incessant Rainfall	1999, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013	13	✓	✓	✓	✓

Note: Hazards like extreme winds/ thunderstorms, flashfloods, landslides and incessant rainfall are correlated as heavy monsoonal rainfall triggers such hazards/ disasters.

Source: J. Parikh, 2015

Table 2: Hazard Timeline of Shillong City (All Year Through)

Hazards	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Flash Floods												
Extreme winds												
Landslide												
Earthquakes												
Thunderstorm/ Lightning/ Hailstorms												

Note: Based on the analysis of data for 30 years

Source: Disaster Resilience Action Plan, Shillong, IRADe, 2021

In Shillong, the slopes are steep, and being a part of young mountains, are highly vulnerable to landslides. In addition, increased rainfall makes the land more unstable and causes a massive flow of debris in every monsoon. Deforestation on the steep slopes due to human activity results in the removal of vegetation cover and exposes rocks, resulting in the weathering processes. Together, these processes trigger landslides (Figure 5) Landslides cause severe disturbance to road transportation and communications, which has a major bearing on the availability of essential commodities, their prices and on national security. The monsoon season in Shillong starts in June and ends around August, accompanied by heavy rains and strong winds. Hailstorms, thunderstorms and squalls commonly occur in the city and its citizens normally face problems during the rainy season. Extreme wind hazards put Shillong city under a very high damage zone, with wind speed ranging from 44 –47 m/s. These high winds usually accompanied by thunderstorms and hailstorms lead to the uprooting of trees and falling of electric poles, thereby damaging telephone cables, streetlights and other infrastructure. Table 2 shows the hazard timeline of Shillong.

Figure 5: Landslide Along Guwahati-Shillong Road Near Ryndang Brier, Shillong (25° 39.107' N and 91° 53.890' E)



Source: Primary Survey (2018), IRADe

Incessant rainfall in the city not only deteriorates the existing physical infrastructure like roads and pavements but also causes a burden of frequent restoration. Moreover, the low-lying areas in the city remain prone to flooding in the monsoon.

Shillong city is highly vulnerable to earthquakes as it falls under the high-risk seismic Zone V and is at risk of experiencing earthquakes at any time of the year (Table 2). The earthquake risk is very high as most of the houses in Shillong have not adhered to building bye-laws. The most vulnerable structures are the stone or brick masonry houses, which have mushroomed in the city in the last several years, replacing traditional 'Assam type' of houses. These houses were usually single-storeyed, made out of wood-based materials and have been resistant to earthquakes with good configurations, lightweight materials used on roofs and walls, flexible connections between various wooden elements at different levels, etc. (Hemant Kaushik, 2009).

Table 3 provides a summary of vulnerability assessment of Shillong city based on the HIGS framework.

Table 3: Vulnerability Profile of Shillong City

Socio-Economic Characteristics	
Population	<ul style="list-style-type: none"> • 2001 Population – 132,867, 2011 Population – 143,229, Growth Rate – 7.79% • The population of Shillong Municipal Board forms 68% of the total urban population of the state (DDMA, Shillong, 2018)
Density	<ul style="list-style-type: none"> • ~ 13,825 per sq km in 2011
Slum Population	<ul style="list-style-type: none"> • 12 slum pockets, total number 2,992 inhabiting 14,458 resides and covering 10% of the city population
Hazard and Extreme Events	
Temperature Observed	<ul style="list-style-type: none"> • Average annual Maximum Temp is 24.95 °C and average annual Minimum Temp is 4.64 °C
Temperature Projections	<ul style="list-style-type: none"> • Ambient air temperature in the state is rising at a rate of 0.031 degrees per year (Water and Climate Lab at the Indian Institute of Technology (IIT), 2020) • The temperature increase is expected to be 1.6-1.7°C by 2050 (SSDMA, Meghalaya, 2015)
Rainfall observed trend	<ul style="list-style-type: none"> • The average annual rainfall of Shillong is 2,162 mm • Hailstorm, Thunderstorm and Squall are the common forms of rainfall in Shillong
Rainfall projections	<ul style="list-style-type: none"> • East Khasi Hills district is expected to experience an increase of 10-15% in precipitation by 2050 (SSDMA, Meghalaya, 2015)
Extreme events Urban Floods/ Flash Floods	<ul style="list-style-type: none"> • Incidences of waterlogging in the city are 25%, with the numbers increasing during the monsoon • August 2014: Incessant rain over 24 hours caused a flash flood in the city • Shillong in July 2019 received more than 72.2 mm of rain resulting in the submerging of low lying areas of the city (<i>The Shillong Times</i>, 2019) • Localities like the polo ground and Pynthorumkhra are highly vulnerable to flash floods every year
Landslides	<ul style="list-style-type: none"> • In 2014, torrential rain-triggered landslides killed almost 8 people in Mawbah area of Shillong (<i>The Times of India</i>, Shillong, 2014) • In 2015, 12 people were killed in the landslides in Meghalaya (Pandey A, 2015) • In 2019 constant rainfall triggered landslides in many places while water in streams and rivers reached the danger level, including the Umkhrah river in Shillong city (<i>The Times of India</i>, 2019).

Hazard and Extreme Events	
Water Scarcity	<ul style="list-style-type: none"> • With the rapid growth of urbanisation, citizens face a shortage of water in the city • Water scarcity in Shillong is related to the problem of water quality as well as water quantity • Over the years a declining trend in rainfall has also been discernible • Stone quarrying has had a destructive influence in Shillong. It has resulted in limited recharge of groundwater and surface water (Meghalaya Basin Development Authority, 2014)
Earthquakes	<ul style="list-style-type: none"> • The city falls under the high-risk seismic Zone V • An earthquake measuring 5.2 on the Richter scale rocked entire north-east India, including Shillong and adjoining Bangladesh in March 2002 (Meghalaya Times, 2016). Another earthquake was recorded in April 2016
Infrastructure Status (AMRUT, NIUA, 2016-17)	
Water Supply	<ul style="list-style-type: none"> • The main source of water supply for Greater Shillong is River Umium • In 2016-17, almost 77% of the households (HHs) had a water supply connection • The per capita water supply is low at 78 litre per capita per day (lpcd) • The extent of non-revenue water is 58% • Water connections are not metered and only 12% of the water services cost is recovered • Efficiency in the collection of water supply related charges (in the municipal area) is 71.3%
Sewerage	<ul style="list-style-type: none"> • Almost 94% of the households in the city have individual and community toilet coverage • 6.47% of HHs have no facilities, hence resort to open defecation • Under Swachh Bharat Mission, 40 individual toilets, 7 community toilets and 115 public toilets are being proposed • There is no sewage treatment plant; all the house sullage (kitchen and bathroom wastewater) drains either into the River Umshyrpi in the south or in the Um Khrah in the north
Solid Waste Management	<ul style="list-style-type: none"> • 159 MT of municipal solid waste is produced per day, 0.4 kg of waste per capita per day. The major solid waste generation sources are households (56%), markets (23%), hotels and restaurants (7%), construction waste (2%), and street sweeping (7%) (Mipun, et al. 2015) • In the SMB area, 46% of the waste generated is collected while outside the SMB area the figure is only 32%, and for the entire GSPA (Greater Shillong Planning Area) the percentage of garbage collected works out to about 41% • Only 43% of households have the facility of door-to-door collection or Community Bin facility. Presently garbage collected is disposed into the gorges of the trenching ground situated at MAWLAI on the Shillong Guwahati road (Shillong Municipal Board)
Storm Water Drainage	<ul style="list-style-type: none"> • The drains run for 148.91 km across the city and drain into the Umkhrah and Umshyrpi rivers • At present (2016-17) the stormwater drainage network coverage is less than 75% of the city, while the incidence of sewerage mixing in drains is almost 100%
Transportation	<ul style="list-style-type: none"> • Total road length of Shillong is 356 km with a road density of 2.05 km/sq. km (Shillong City Development Plan) • NMT (Non-Motorised Transportation) has not being stressed upon in the city Comprehensive Mobility Plan (CMP) due to undulating topography and operational constraints

Hazard and Extreme Events	
Power	<ul style="list-style-type: none"> The average electricity consumption in the residential area is 300 units /house/day and in the commercial area is 450 units /shop/day A total number of 378 solar street lights are available under MECL. No smart metering is introduced yet The agencies responsible for the supply, management and distribution of electricity in the city are: (1) North Eastern Regional Electricity Board, Shillong; (2) Meghalaya State Electricity Board, Shillong; and (3) NEEPCO (North Eastern Electric Power Corporation Limited)
Housing	<ul style="list-style-type: none"> Out of the total households in Shillong city, about 46% are made of concrete, followed by wood and burnt bricks. RAY survey in 2015 addresses 13,120 number of slum households, with 42% notified slums. SMB constitutes 5426 no. of slums Out of the 65 slums in Shillong UA, except for 2, the rest are on private land (Ministry of Housing and Urban Poverty Alleviation, GOI, 2015) Housing for All Plan of Action for Shillong indicates 2,296 housing demand from EWS & LIG categories under the Beneficiary-Led-Housing (BLIC), Credit Linked Subsidiary Scheme (CLSS) and Affordable Housing in Partnership (AHP) component (Smart City Shillong proposal 2016)
Governance	
Administrative Units assigned to address climate change	<ul style="list-style-type: none"> Shillong Municipal Board is responsible for service delivery; this includes water supply, solid waste management, etc. East Khasi Hills District Commissioner's office is quite active in the area of disaster risk reduction and disaster management planning Meghalaya Climate Change Centre, established under National Mission for Sustaining the Himalayan Ecosystem (NMSHE) in October 2015 Meghalaya Basin Development Authority, Meghalaya Disaster Management Authority and state government are important stakeholders
Initiatives of the city to address Climate Change	<ul style="list-style-type: none"> The Forest and Environment Department, Government of Meghalaya along with the Meghalaya Basin Development Authority with Technical Support from GIZ organised the 'Expert Consultation Prioritising Actions under Meghalaya's State Action Plan on Climate Change (SAPCC)' in May 2013 and Meghalaya State Action Plan on Climate Change developed in 2015 The local government, including Shillong Municipal Board (SMB) and district unit is implementing Urban Risk Reduction (URR) and Disaster Risk Reduction (DRR) programme with support from UNDP. This also involves the integration of risk reduction into urban development programmes while assessing risk and vulnerabilities and strengthening building codes, bye-laws and development control regulations (DCR) ULB and UNDP (United Nations Development Programme) are also working on developing ward-level risk assessment, including an understanding of the existing early warning systems, identifying formal and informal mitigation actions and recommendations.

The Rapid Vulnerability Assessment for Shillong indicates gaps in the existing urban basic infrastructure and socio-economic conditions of the city. It records the scarcity of water supply with the per capita water available being only 78lpcd. Only 46 per cent of the waste generated is collected in the municipal area. With the absence of sewage treatment plants, the city has reported mixing of sewerage water with stormwater during periods of high rainfall.

Recommendations

Effective disaster management systems are essential to mitigate the impact of disasters (Garschagen, 2016). The system needs to involve government, civil society, communities, and the private sector (Wilkinson, 2012), who are some of the major stakeholders in disaster management.

This study provides key recommendations for improving the disaster resilience of the Shillong area. They are sector specific and relate to:

- **Infrastructure**– Construction and building bye-laws, critical infrastructure, drainage and sanitation systems.
- **Hazard management**– Hazard disaster mapping, early warning systems, administration and governance, socio-economic development.

Infrastructure

Building Bye-Laws and Construction

- The building vulnerability of Shillong city is comparatively high. Standardised concrete buildings result in increased risks. More use of indigenous materials, bio-engineering and traditional techniques act well during earthquakes and construction of multi-storeyed buildings along in hazard-prone areas should be restricted.
- Review of the existing building bye-laws and hazard inclusive necessary updates are required instead of standard laws and should ensure implementation of the same. There is a need to amend existing building regulations and/or enforcement mechanisms to make them more appropriate.
- Disaster resilience has a direct impact on a unit level. Disaster relief enforcement and monitoring of the existing provisions for building infrastructure and disaster-resilient systems need to be strengthened.
- A standard soil map is needed in line with a stability zoning map to avoid need-based risk computation in the city. It should be made mandatory for buildings to obtain a certificate of structural safety before approval by a local body.

Critical Infrastructure

- Critical infrastructures - hospitals, schools, evacuation structures (e.g. multipurpose cyclone shelters), fire stations need to be highlighted with their locations on ward level maps.
- The Action Plan needs to include the location of infrastructure on low disaster susceptible grounds so as to make them functional at times of disaster emergencies.

Drainage and Sanitation

- There is an immediate need to design and develop a drainage master plan for the city.
- Lack of sewerage management is affecting the water quality of the water bodies as well as groundwater. This also contributes to incidences of waterlogging in the city. The integrated sewerage development plan needs to be developed and should be prioritised for investment.

- Standard streams and spring dimensions often do not consider the factor of respective volume, high flow, abutting land use and likewise. There is a need for customised designs to cater to improved stormwater drainage. In addition, there is a need to develop a Storm Water Drainage Network across the city and a separate water treatment plant to filter the sewage before releasing it into the rivers.
- Dumping of solid waste in natural streams and springs often leads to disruption of the natural flow of water. This needs to be restricted to avoid waterlogging and flooding which leads to landslide and soil erosion.

Hazard Management

Hazard/Disaster Mapping

- A statistical overview of the frequency of occurrence and intensity of different types of hazards is needed, along with ward level disaster susceptibility records. Records related to the history of hazards and infrastructure details of health centres should be maintained and updated on a regular basis.
- There is a need to develop a Hazard/Risk-specific Disaster Action Plan, with a comprehensive view of all-natural disasters (IRADe, 2013) Develop maps at the scale of 1:4000 and map hazard/risk-wise vulnerable zones.
- A hazard inventory needs to be developed to analyse impacts and develop the required mitigation measures. Hazard susceptibility needs to be mapped based on slope profile, city land-use pattern, land elevation, slope aspect, drainage pattern, rainfall pattern and likewise.
- The Emergency Operation Centre should be strong and active and ensure that the physical space is set up in a safe zone, whose vulnerability to hazards is relatively low.
- There should be a regular update of the disaster database for future reference. Disaster communication systems need to be strengthened so that on the onset of disasters early warnings pertaining to the disaster can reach all the citizens of the city well in advance.

Early Warning System

- Flood Early warning systems should be set up to coordinate and facilitate pre- and post-disaster operations. They should be the functional component of the City Disaster Management Plan.
- Installation of Landslide Early Warning System (LEWS) and slope monitoring for real-time early warning system.
- The current status of early communication on risk events is limited to only a few select agencies. It is essential to upgrade the current early warning system in the city significantly to meet the requirement of reducing fatalities and protecting infrastructure/assets from future events. An annual review and measuring of performance by targeting for different scenarios is needed.

Administration and Governance

- Integrated land-use planning needs to be initiated at the city level. Disaster resilience action plans should be developed and plans should be made dynamic with lessons from each city to be integrated for better land use planning, governance and response mechanisms.

- On the state and city governance front, the functioning of the agencies needs to be streamlined and made accountable to improve service delivery. Single point central offices are also needed for a consolidated Database Management System (DBMS) for effective and efficient planning.
- The current role of the city ULB is limited in disaster management activities within the city. There is a need for more localised actions, further magnified from the district level. There should be strengthening of interdepartmental coordination and sharing of responsibilities to ensure easy recovery at the time of crisis.
- For better functioning of EWS at the city level, there is a need to strengthen the network among city institutions, encourage partnerships and build capacities of all key stakeholders.
- The Emergency Operation Centres (EOCs) should be equipped with the necessary types of equipment and the latest technology. There should be well trained staff in EOCs, which should be located in safe zones to avoid obstruction in their functioning during floods.
- The Shillong Municipal Board needs to build capacity in disaster management at different levels, e.g. individual, community, NGO, official, implementation, and the ULB level.
- City ULBs should make location-specific Standard Operating Procedure (SOP) (NDMI 2018) for the flooding issue in the city. This SOP should be in line with the SOP for flooding released by the Ministry of Urban Development (May 2017).

Socio-Economic

- The slum settlements across the city are located in areas which are prone to landslides and flooding (along the banks of rivers Umkhrah and Umshyrpi). Sparsely populated areas along the river banks increase the vulnerability of slum settlements in these areas to landslides. In the thickly populated areas along the river there have been a lot of encroachments on to the rivers/streams. A slum rehabilitation plan should be made in order to protect the most vulnerable.
- Increasing public awareness and education is the key to spreading the culture of safety. Awareness regarding proper land use as well as sustainable land management needs to be provided.
- Special reference needs to be made to vulnerable section of the society (including, women, children, elderly and the economically weaker section) and migrants (floating population) who live in rented houses.
- Community capacity building programmes, and public awareness campaigns add to improved sensitisation.

Table 4: Roles and Responsibilities of Implementing Agencies

Implementing Agencies	Roles/ Responsibilities
Indian Meteorological Department (IMD)	<ul style="list-style-type: none"> • Weather forecasting and disseminating weather information • Provision of Information to Urban Local Bodies on extreme weather events
Geological Survey of India (GSI)	<ul style="list-style-type: none"> • Geomorphology and Soil mapping • Document and update hazard inventory database • Landslide & earthquake prediction and provision of information through common portal
Department of Land Revenue and Disaster Management – Meghalaya Disaster Management Authority	<ul style="list-style-type: none"> • Planning, coordinating and monitoring disaster prevention, mitigation, preparedness and management • Developing multi-hazard/disaster management plan – city level • Mapping multi-hazard risk and vulnerability profile of Shillong • Installation, gathering, managing and disseminating the early warning/relevant information • Capacity building and mock drills/ training • Amendment of Building Bye-Laws • Installation of Landslide Early Warning Systems (LEWS) and Flood Information System - Hydrological Cycle Observing System (HYCOS) • Installation of sustainable structural measures or slope landscaping such as retaining wall for landslide mitigation • Streams or Channel improvement, catchment-wide interventions and related structural measures for flood mitigation
Urban Affairs Department, Govt. of Meghalaya	<ul style="list-style-type: none"> • Construction and maintenance of buildings (residential & non- residential) • Amendment of building bye-laws • Work in close collaboration with state government and Urban Local Bodies (ULBs) in terms of urban development and implementing housing schemes • Assisting and guiding ULBs in terms of their functioning and execution of duties
Public Health Engineering Department, Meghalaya	<ul style="list-style-type: none"> • Provision of adequate safe water and sanitation • Water supply connection and sewer line connection – plan and execution of plans • Functioning of city sewerage treatment plants for safe disposal of effluents and the water treatment plants
District Disaster Management Authority	<ul style="list-style-type: none"> • Search and rescue operations • Relief and rehabilitation • Traffic management during hazards • Provide required guidance and cooperate with the ULBs during disaster and disaster mitigation
Ward Level Disaster Management Committees	<ul style="list-style-type: none"> • Review and analysis of ward level hazard vulnerabilities • Work in coordination with District Disaster Management Authority (DDMA)
Urban Local Bodies: Shillong Municipal Board	<ul style="list-style-type: none"> • Sanitation and Solid Waste Management • Drainage mapping and planning of stormwater drainage system and sewerage network • Relief and Rehabilitation of city slums/ urban poor • Clearing of streams and springs • Perform other duties relating to Disaster Management as assigned by the Disaster Management Authority

Conclusion

The north-east region as a whole is expected to see an increase in average annual rainfall by 2030 with respect to 1970. With an average annual rainfall of 2,162 mm, Shillong is in close proximity to one of the wettest places on earth—Cherrapunji. The city has also experienced rapid rise in temperature over the last 50 years. For the east Khasi hills district (Shillong) the temperature increase is expected to be 1.6-1.7°C by 2050 (SSDMA, Meghalaya, 2015). These predicted climatic changes will exacerbate the impacts of natural disasters like flash floods and landslides that the city is already vulnerable to, along with risk of earthquakes, thunderstorms/lightning, forest fires and water scarcity.

Along with climate changes, the urban population has been gradually increasing from 1901 to 1991. However, the growth rate has reduced remarkably due to the growth of satellite towns in the Shillong Urban Agglomeration. The slum settlements in the city are located in areas which are prone to landslides and flooding, and erosion in sparsely populated areas along the banks of river Umkhray and Umshyrpi is increasing the vulnerability of slum settlements in these areas to landslides.

The urban vulnerability risk assessment indicates huge risks due to existing building practices and building bye-laws and the lack of need and nature-based development and adoption of traditional knowledge in the building and construction process. The existing physical and socio-economic infrastructure is also unable to cater to the basic urban requirements.

Over the decades the Meghalaya Disaster Management Authority and the District Disaster Management Authority, Shillong, have developed Disaster Management Plans to mitigate and manage disasters across the state and district levels, like the Meghalaya State Disaster Management Plan, 2006, District Disaster Management Plan, East Khasi Hills District, Shillong, 2015, 2016, 2019-20, The plans assess the existing vulnerability of the people in the state to various disasters as well as the capabilities of various state-level organisations in promoting and strengthening disaster management activities. The City Disaster Management Plan, 2018 prepared by NESAC, Umiam for the District Disaster Management Authority (DDMA) includes a multi-hazard preparedness plan for Shillong city to address the city's response to a multi-hazard disaster preparedness situation which may affect large areas causing extensive damage to life, property and environment and consequent epidemics.

The study indicates a need for strengthening the institutional framework and the mechanism for effective data management and coordination amongst the various government departments and institutions. The existing gaps in the urban infrastructure and the hazard management system need to be looked into. With the review and updating of the existing building-byelaws, there is a need to adopt indigenous material and bio-engineering techniques for construction purposes. The existing critical infrastructure needs to be mapped at the ward level and related (if required) on low disaster susceptible grounds. Proper stormwater drainage networks have to develop to reduce incidences of waterlogging along with a separate water treatment plant to filter the sewage before releasing it into the rivers.

For hazard management, a hazard zoning mapping is essential with updated hazard inventories and impact assessment. Disaster communication systems need to be strengthened with the installation of Early Warning System (EWS) and slope monitoring for a real-time early warning system. There is a

need to update the existing mechanism of data collection, and coordinated planning process. Single-point central offices need to be established for a consolidated Database Management System (DBMS), along with defining roles and responsibilities of the urban local bodies. Slum pockets and population distribution need to be mapped and a rehabilitation plan should be made in order to protect the most vulnerable.

A Disaster Action Plan needs to be developed for the city, with ward-wise mitigation and adaption plans with local ward level committee being set up to ensure adequate community participation. Community-level capacity building, awareness, and participatory planning need to be encouraged.

This process can be replicated and used for developing short- medium- and long-term structural and non-structural resilience action strategies/measures for other Himalayan cities. Such strategies will assist to mitigate risks and adapt to the existing physical and socio-economic vulnerability needs while providing a detailed implementation framework to strengthen the governance and administrative structure of the city. It is also essential to procure and strengthen the early warning systems and preparedness methodology for improved risk management.

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