Disaster Vulnerability Assessment & Action Plan to Strengthen Disaster Resilience of Gangtok, Sikkim

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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. Along with the increasing urbanization, IHR is also expected to experience severe impacts of climate change in the near future. Urbanisation exerts additional environmental stress and amplifies the impact of natural disasters. Physical and socio-economic vulnerabilities of cities posed by disasters are often accompanied by a lack of necessary resources – financial, human, and institutional – as well as access to relevant scientific information to cope with them. Inefficient governance along with inadequate infrastructural services also increase the vulnerability of socially and economically marginalized populations living in urban areas.

A Vulnerability Assessment Framework (VAF), based on parameters of Hazard exposure, climate scenarios and projections, basic and critical infrastructure and services, governance structure and socioeconomic status of urban areas has been used to assess the disaster vulnerability of Gangtok city, Sikkim. The analysis indicated that the city remains vulnerable to disasters like earthquakes, landslides, flash floods and enlists the gaps in the existing infrastructure and services along with the Governance. In lieu of the existing vulnerability, it becomes necessary to devise strategies and plans to develop disaster resilience plans. The paper has done the vulnerability mapping and sector specific recommendations for building disaster resilience of Gangtok city.

Keywords: *Indian Himalayan Region, Natural Disasters, Urbanization, Vulnerability Assessment, Disaster Resilience, Adaptation Strategies*

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1. Introduction

The Global Climate Risk Index report 2020 (David Eckstein et. al., 2020) ranks India 5th in 2018 in global vulnerability citing the highest recorded number of fatalities due to climate change and the second-highest monetary losses from its impact in 2018. India lost around 2,736 lives in 2017 due to disasters, with an economic loss of around USD 13,789 million, the 4th highest in the world (Eckstein D. et. al., 2019).

India is exposed to multiple natural disasters, like earthquakes, floods, cyclones, landslides, tsunami, and heat wave. Out of 36 states and union territories (28 States and 8 Union Territories) in the country, 27 of them are disaster-prone (NIDM).

The DM Act 2005 uses the following definition for disaster: "Disaster" means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade 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 GoI, 2016

During 1980-2010, India has experienced nearly 431 natural disasters killing around 1.4 lakh people and affecting around 15 crores people, with an economic loss of USD 48.06 billion (EM-DAT, 2019). With growing urbanization 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).

Indian Himalayan Region (IHR) covers around 16% of India's total geographical area, spread over 12 states (ENVIS, 2018). The Himalayan region is one of the four most vulnerable areas to disaster, including earthquakes, floods, landslides, and forest fires (MoEFCC, 2016). On average, IHR is hit by 76 disasters, killing 36,000 people and affecting 178 million people every year (United Nations-affiliated organization, 2013). Landslides frequently affect the IH and nearly 127 landslides events were reported between 2009-2018 (Khadka, 2021).

Indian Northeast (NE) region in India part of IHR is particularly vulnerable to natural disasters, due to its fragile geo-environmental settings and economic

underdevelopment. Rapid growth is currently taking place in the environmentally sensitive region/non-urbanized region of the Himalayas. From a completely economic standpoint, this may seem ideal, at least in the short run, however, the unplanned accommodations made to adapt to such rapid changes have resulted in environmental degradation (Anbalagan, 1993). The increasing levels of urbanization, 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.

> A natural hazard turns into disasters due to 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 (Parikh. J.2014) (https://irade.org/Disaster%20Resilient%20Cities.pdf

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 affects disaster risks in two ways - increase in weather and climatic hazards, and through an increase in the vulnerability of communities to natural hazards, particularly through ecosystem degradation, reduction in water and food availability, and livelihood changes.

The paper presents the results of the vulnerability assessment of Gangtok city, Sikkim to develop a disaster resilience plan by highlighting their exposure to potential hazards and developing city-level resilience to build strong infrastructure, able governance, and good socio-economic conditions.

The paper is a part of a study carried out through the support of the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India (GoI), under the National Mission on Himalayan Studies (NMHS) to design and develop Disaster Resilience Action Plan for Indian Himalayan cities.

2. Study Area

2.1 Gangtok Sikkim

Gangtok the capital and the largest city in the Indian state of Sikkim and the headquarters of the East Sikkim district is located in the eastern Himalayan range, at an elevation of 5,410 ft above mean sea level and located at 27°20 N & 88°37 E. (Refer to figure 1 Gangtok city location and municipal boundary with wards). The city is flanked on east and west by two rivers, namely Roro Chu and Ranikhola, respectively. These two rivers divide the natural drainage into two parts, the eastern and western parts. Both the streams meet the Ranipool and flow south as the main Ranikhola before it joins the Teesta at Singtam. The climate in the city is monsoon-influenced subtropical highland climate or the Himalayan type of climate. The average maximum during summer season is around 22˚C, with maximum temperatures rarely crossing 25°C and minimum temperatures during the winters being recorded at 3˚C. Rainfall starts from the pre-monsoon in May, and peaks during the monsoon, with July recording the highest monthly average of 649.6 mm. The region receives an annual rainfall of 3494 mm over 164 rainy days.

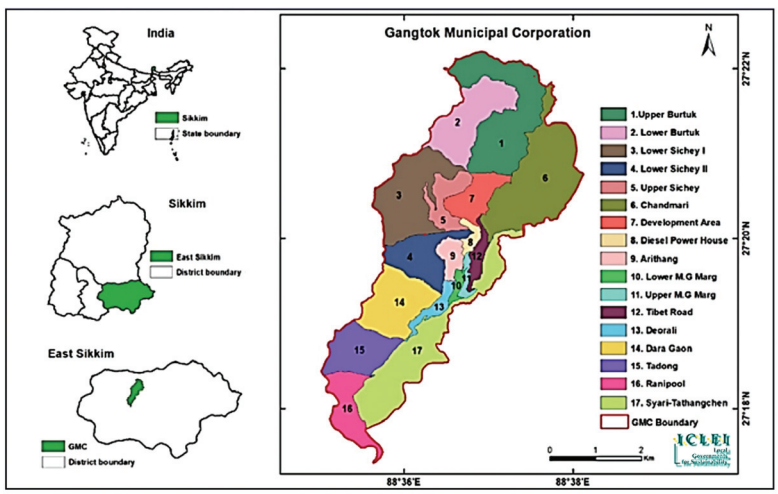

Figure 1: Location Map of Gangtok showing the Municipal Boundary and the Wards of the City

(Source: Gangtok Disaster Resilience Action Plan, IRADe, 2020-21)

The Gangtok municipal area was notified in the year 2010, comprising of 15 municipal wards and areas covering around 19.016 sq. km. The total wards have increased to 19 wards since 2020 (UDD, 2020). The total population of the city is 100,286 (Census 2011), hence the population density of the city is 5223 persons per sq. km.

The city of Gangtok is most vulnerable to earthquakes as it falls under the high-risk Seismic Zone IV and V. Apart from the earthquake, torrential rainfall triggers flash floods and landslide incidences, blocking roadways and connectivity to the city. Along with these, the city is vulnerable to hailstorms/thunderstorms and forest fires.

3. Data & Methodology

To understand and analyze the vulnerability and climate-resilient measures in Indian Cities, a Vulnerability Assessment Framework (VAF) was designed by IRADe in Asian Cities Climate Resilience, Working Paper Series 8, IIED (Jyoti Parikh et al., 2014). The Framework was developed based on four themes "Hazards-Infrastructure-Governance-Socio-Economic characteristics (HIGS)". The framework was developed to systematically understand urban issues that shape climate-resilient urban development and help shape policies and projects developed by cities to address these risks. City-level disaster risks can be analyzed using the HIGS framework that integrates information on physical and meteorological Hazards, analysis of urban infrastructure and services, Governance variables, Socioeconomic and demographic indicators This Vulnerability Assessment Framework (refer to Fig 2) provides a customizable approach for cities to analyze their vulnerabilities to understand the potential areas of corrective actions as well as enable 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 policymaking on urban development and management. What is particularly valuable is that the vulnerability assessment methodology can spur autonomous action by enabling cities to assess their vulnerabilities using the HIGS framework and prioritize response strategies.

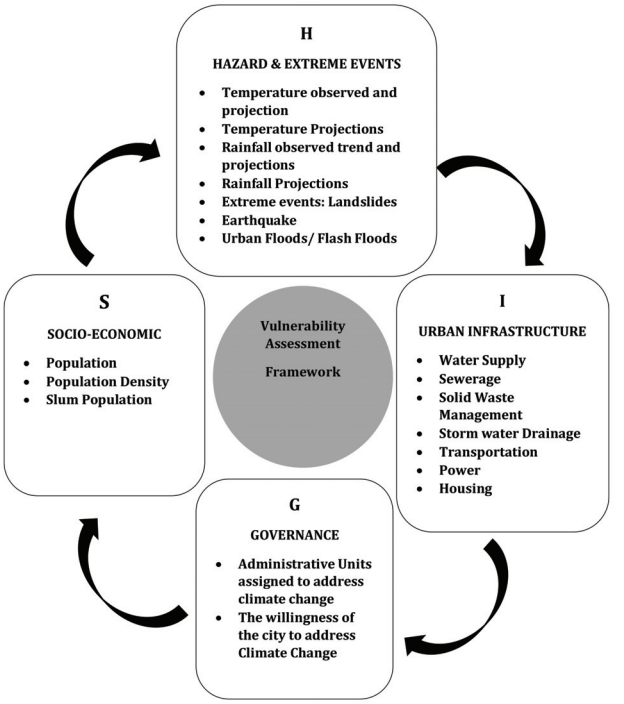

Figure 2: Vulnerability Assessment Framework and detailed list of variables

This Vulnerability Assessment (HIGS) framework was further improvised and first applied by IRADe on twenty Indian Cities for assessing their vulnerability to natural hazards. Later in 2012-14 IRADe further evolved the 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, et al., 2015). The holistic framework HIGS (J. Parikh, et. al., 2015) was further improved and extended for assessing disaster resilience in 10 cities (R. Magotra, et. al., 2019) by incorporating parameters that give local/regional diversification, flexibility, and interdependency (flow of information) to be customized for the use in other regions/cities. The HIGS (RVA) framework is further made more dynamic by adding more climatic parameters (temperature, precipitation, climatic scenarios, and projections, etc.) and evaluating their status. Methodology in this study revolves around collecting secondary information from the city and analyzing them concerning:

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.

The data for Gangtok 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 analyzed to assess each of the four aspects (Hazard, Infrastructure, Governance, and Socio-Economic Conditions) of the framework are:

Hazard and extreme events: Exposure to geophysical variables; history of hazards, their frequency of occurrence, and magnitude of impact. Climate variables observed and projected.

Infrastructure Status: Water supply, waste management, stormwater drainage system status, power, and transport infrastructure, the status of the infrastructure, maintenance, coverage, and access to the basic infrastructure.

Governance: The institutional framework of the city management, urban administration, public health, response, recovery system, and evaluation of city management in the context of disaster proneness, financial status/independence of the Urban Local Bodies, and efficiency in delivering the basic services. Smart initiatives like E-Governance, ICT (Information and Communication Technology)

Socio-Economic: Population and urbanization 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 them into their developmental activities.

Urban Vulnerability Assessment framework was used to assess the disaster resilience of Gangtok. The Vulnerability Assessment Framework was used to assess the urban

vulnerability of the Gangtok and to bring forth the areas of adaptation which the cities should prioritize for improving its resilience and integrate it with their developmental initiatives.

4. Analysis and Discussion

4.1 Disaster Vulnerability of Gangtok City

Sikkim is among India's most vulnerable regions to both natural and human induced disasters due to its location in the very high zone in terms of an earthquake and high zone in terms of landslides (SSDMA, 2012). A large portion of the Sikkim territory including Gangtok is covered by the Precambrian rock comprising of phyllites and schists and therefore the slopes are highly susceptible to weathering and prone to erosion. As a result, landslides are frequent, isolating the numerous small towns and villages from the main city (UDHD, Govt. of Sikkim). Surface runoff from water by natural streams (locally called jhora) and man-made drains, has contributed to the risk of landslides. Table 1 highlights the hazard exposure month of Gangtok during a year.

Table 1: Hazard Exposure and Timeline, Gangtok

Index	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Landslides												
Flash Flood												
Hailstorm/ thunderstorms												
Forest Fire												
Earthquake												

High-intensity torrential rains may bring flash floods and trigger more landslide incidents, which may block Gangtok's land connection with the rest of the country. In 2012, 22 people were reportedly killed due to flash floods, which also washed away nearly 30 km of highway in North Sikkim (Kundu, A, 2012). Flash floods might also trigger a series of landslide incidences, which in turn compound the vulnerability of the people. During 1957 – 2005, the East Sikkim district had experienced over 153 landslide

incidences. Nearly 7.51% area of Gangtok city falls in a very high-risk zone with respect to landslides potentially affecting 1.84% of the total settlements while 24.64% of the area falls under the medium high-risk zone with 18.18% of the total settlements being affected (SSDMA, 2012).

In addition to flash floods and landslides, Gangtok is also prone to earthquakes. The entire state falls in highly Seismic Zone IV/V of the earthquake zonation map of India. Around 29% of the city's area falls in the very high-risk zone affecting 18.84% of the total settlement, 13.45% of the area fall in the medium high-risk zone affecting 14.80% of the total settlement, and 31.48% of the area categorized to be in medium risk zone with 42.14% of the total settlement being affected (SSDMA, 2012). The loss of lives in past earthquakes have occurred due to the collapse of buildings, constructed with stones, bricks, adobes, and wood, which were not particularly engineered to be earthquake resistant. Table 2 provides a summary of the vulnerability assessment of Gangtok city.

Table 2: Vulnerability profile of Gangtok city

Socio-economic Characteristics	
Population	• 100,286 (2011 Census)
Population Density	• 5,223 persons per sq.km
Slum Population	• 20,504 (6,085 HHs) Notified & Non-notified slums (SFCPoA, Gangtok, 2013)
Hazard and Extreme Events	
Temperature Observed	• Gangtok has a mild, temperate climate all year round (Gangtok Municipal Corporation, 2020) • Maximum & Minimum Temperature (2016) – 27°C & 19°C respectively (Gangtok Municipal Corporation, 2020)

Temperature Projections	• By the 2030s, the average annual temperatures for Sikkim is projected to rise by 1.8 to 2.1°C with respect to the 1970s (SSDMA & GMC, 2015)
Rainfall Observed Trend	• Pre-monsoon rainfall in May • Most of the rainfall in July-September, with July recording the highest monthly average of 649.6 mm (25.6 in) (SSDMA & GMC, 2015) • Snowfall in the months of December and January were recorded in the year 1990, 2004, 2005, & 2011 (SSDMA & GMC, 2015)
Rainfall Projections	• Sikkim is expected to experience a decrease in precipitation of about 3% in 2030 with respect to 1970 (SSDMA & GMC, 2015)
Extreme Events: Landslides	• Almost 71 landslide events being registered in the city (1990-2017, sharp rise recorded between 2001-2017) • In 2016 landslide hit the Sikkim-Bengal border, resulting in the death of an unspecified number of people • In 2015, Landslides near Rambhi, in the outskirts of Siliguri, on the way to the hills have disrupted the road traffic between Gangtok and the North Bengal hub.

Earthquake	• Sikkim is placed in Zone IV/V of the earthquake • Major earthquake affected area are in and around below Arithang, below Paljor stadium and area around Amdogolai and Burtuk. • 6.9-magnitude earthquake hit Sikkim in September 2011 that killed 70 people and destroying several villages.
Urban Floods/Flash Floods	• Flash flood killed 22 people in 2012, triggered a series of landslides and washed away nearly 30km of highway in north Sikkim amid torrential rain Friday evening.

Urban Infrastructure	
Water Supply	• At present, the per capita water supply in the city is 129 lpcd (Gangtok Smart City Mission, 2018-19) • Nearly 19,811 (82.7%) households have water tap connection, with 75% of the Households having treated water supply. After connections Total length of the water supply distribution pipeline laid in the City is 203.64 Km (Gangtok Municipal Corporation, 2020) • River Rateychu is the existing source of water, and there is one WTP at Selep (capacity 41 MLD), demand being 45 MLD and check leakage (around 79%) (Gangtok Municipal Corporation, 2020)

Sewerage	• The city has 42% coverage of sewerage network services, with 96% coverage of individual & community toilets (SPCB, Sikkim, 2020-21) • The sewer system and stormwater drainage systems are separate in Gangtok. There is no treatment facility for the drains which are presently being discharged directly into the natural streams
Solid Waste Management	• The city generates about 50 Metric Tons per day (TPD) of solid waste daily (SPCB, Sikkim, 2020-21) • Almost 100% of MSW is collected , but only 15 (TPD) is treated and rest 35 TPD is disposed at the dumping site (SPCB, Sikkim, 2020-21) • No provision for the collection & disposal of hazardous toxic wastes generated from industries. • Declared the best among the top 10 cleanest cities in India, 2015. Gangtok Municipal Corporation (GMC), along with a local NGO named "24 hours Inspired", has developed a programme called "Engage 14 programme" to engage school children in the process of understanding SWM. • The Corporation has already initiated works to improve the situation at the Martam landfill site (Gangtok Municipal Corporation, 2020).

Stormwater Drainage	• There is a gap of 75.99% in the coverage of the stormwater drainage network (24%). (SPCB, Sikkim, 2020-21) • Roadside drains cover 37740m, out of which 28.09% are still earthen or below the required capacity (SPCB, Sikkim, 2020-21). • 25-30% incidence rate of sewerage mixing in the drains. • The incidence of waterlogging prevalent status is 4.72% (SPCB, Sikkim, 2020-21).
Transportation	• The share of personal vehicles and taxis combined is 98% of Gangtok's total vehicles, a high percentage when compared to other Indian cities. (NIUA, 2016) • The 1 km (0.6 mi) long cable car with three stops connects lower Gangtok suburbs with Sikkim Legislative assembly in central Gangtok and the upper suburbs. • Under AMRUT Transportation sector has been given preference by stressing on public transport or constructing facilities for non-motorized transport (e.g. walking and cycling). 11 projects have been initiated by the city (AMRUT, 2017-18)
Power	• Electricity is supplied by the power department of the Government of Sikkim. Gangtok has a nearly uninterrupted electricity supply due to Sikkim's numerous hydroelectric power stations.

Housing	• Urban Development and Housing Department is the nodal agency for providing individual urban housing in the state. • As per UD&HD, Govt. of Sikkim, the city has around 30,328 houses occupied by 23773 households with an average household size of 4 persons (2011) • 66.18 % of the houses are permanent in structure (Census 2011)

Governance

Administrative Units assigned to address climate change & Disaster Management	• Sikkim State Disaster Management Authority – state-level institution for planning, coordinating and monitoring disaster prevention, mitigation, preparedness and management • Department of Land Revenue and Disaster Management - nodal agency for looking after disaster response, mitigation, preparedness and prevention
Administrative Units assigned to address climate change & Disaster Management	• District Disaster Management Authority, East District - includes District Core Committee for Crises Management, District Crisis Management Sub-Committee for Search & Rescue Operation and Relief & Rehabilitation • Gangtok Municipal Corporation- responsible for Sanitation and Solid Waste Management

Administrative Units assigned to address climate change & Disaster Management	• IMD & GSI - weather forecasting and disseminating weather information and hazard early warning • Municipal Disaster Management Committee, Ward Disaster Management Committee etc.
The willingness of the city to address Climate Change & Disaster Management	• The city has taken proactive initiatives and has developed very good practices for disaster resilience which includes: • Disaster Management Plan 2020-21 & 2018-19, East Sikkim, SSDMA • Report on Human Vulnerability Due to Natural Disasters, Sikkim, SSDMA, 2018 • Gangtok City Disaster Management Plan (Evacuation and Response), 2015 • Multi-hazard Vulnerability Assessment, East Sikkim Gangtok, 2012 & 2018, SSDMA • Comprehensive Mobility Plan, 2010 • CDP Gangtok

The Vulnerability Assessment of Gangtok provides a comprehensive understanding of the existing urban basic infrastructure and socio-economic condition of the city and their vulnerability to various hazards and the existing administrative and governance structure to mitigate and adapt to the same.

Hazard and Extreme Events: The city is most vulnerable to earthquakes followed by landslides and urban floods. Owing to the climatological changes projected with rising temperatures and changing patterns in annual rainfall, the city is expected to experience adverse effects of climate change and an increase in hazard events.

Infrastructure Status: In terms of the basic infrastructure and services, the availability of potable water is an important issue, with outdated and dilapidated water supply pipelines, regular leakage, and shortage of water is experienced in many parts of the city. A system for the collection and disposal of hazardous waste needs to be developed along with the up-gradation of the existing landfill site at Martam, East Sikkim (SBCP Sikkim, 2019-20).

Along with the increasing urban population, the city experiences a heavy flow of floating population (working migrants & tourists) hence, provisions are required in the sectors of public transportation and housing sector in the city.

Governance: The administrative and governance structure of the city to manage disaster has been well laid, however, there is a need to define the role and responsibilities of each department and organization to mitigate disasters not only during or post-disaster occurrences but also in the pre-disaster management process and initiating disaster early warning and developing and updating disaster database.

Socio-Economic: the city is one of the fastest-growing urban areas in the NE region with an increasing population growth rate, hence, increasing the population exposed to disasters. With over 58 slum pockets scattered across the city, the vulnerability risk on the people exposed to disaster is also high for Gangtok city

5. Recommendations

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

Based on the study, some of the sector-specific recommendations for improving the disaster resilience of Gangtok city has been related to:

- Infrastructure - Construction and building bye-laws, Critical Infrastructure, Drainage, and sanitation systems.
- Hazard Management – Hazard disaster mapping, Hazard Early Warning Systems, Administrative and Governance, and Socio-economic development.

5.1 Infrastructure

5.1.1 Building bye-laws & Construction

- Gangtok follows the Sikkim Building Construction Regulations, 1991 (As amended by the Sikkim Building Construction (Amendment) Regulations, 2000), and the National Building code and Delhi Master Plan(s), which needs to be amended from the prescriptive to form-based/performance-based/site-specific, and formulation of a new enforcement mechanism .
- Nature-based construction technology adaptation and Bio-engineering measures should be given top priority.
- The northern wards, Burtuk and Chandmari are highly susceptible to landslides, owing to the higher elevation and slope among other aspects, hence new construction projects in these areas should have a clear plan on how multi-hazard disaster mitigation design and features shall be integrated into the construction.
- There is a need to develop a standard soil map in line with the stability zonation 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. Hollow concrete blocks, precast stone blocks, concrete blocks, and stabilized soil blocks can be used for construction purposes.

5.1.2 Critical Infrastructure

- Critical infrastructures like hospitals, schools, power generation and distribution centers, evacuation structures (e.g. multipurpose shelters), fire stations likewise need to be highlighted with their locations on ward level maps.

- Action Plan needs to include the location of rescue and relief infrastructure to make them functional at times of disaster emergencies.
- Systematic investigations and remedial action need to adapt to restore and conserve heritage and critical Infrastructure.
- Inspection of all structural measures twice a year, once before the commencement of the monsoon and again after the monsoon has withdrawn and ensured that restoration/strengthening measures of vulnerable spots are carried out (NDMA guidelines).
- With the increasing urbanization and tourism, Gangtok will experience vertical growth in the future, hence it becomes necessary for geo-coding buildings, basic and critical infrastructure at ward level. Basic infrastructure like potable water supply and other basic infrastructure will become a significant issue with growing urbanization, and ULBs need to consider management plans for the same.

5.1.3 Drainage and Sanitation

- Need to map the drainage pattern of the city and its neighboring areas, including streams and jhoras, as most of the landslide incidences are located near such streamlines.
- Need to develop Sewerage treatment plant, as the untreated sewer system and stormwater is discharged into the natural streams.
- The solid waste is usually dumped in the johras with no compliance. The dumping of solid waste in johras often leads to the disruption of the natural flow of the water. This results in the increased vulnerability to waterlogging and flooding, causing landslide and soil erosion in the city.
- Need to develop provision for collection & disposal of hazardous toxic wastes generated from industries.
- Clearing of culverts and jhoras and stabilization of roadside drain along all important roads.
- Catchment-wide interventions (agriculture and forestry actions and water control work). Constructing new channels or improving the discharge capacity of the present drainage system. Diversion of floodwaters into natural or artificial constructed channels or basin.

5.2 Hazard Management

5.2.1 Hazard/disaster Mapping

- A statistical overview of their frequency of occurrence and intensity is needed, along with ward-level disaster susceptibility records required. Records related to the history of hazards and infrastructure details of health centers, which are easily available needs to be maintained and updated regularly.
- Need to develop a Hazard /Risk-specific Disaster Action Plan, with a comprehensive view of all-natural and manmade disasters. (IRADe, Analytical Report for CDMP Review of Six Cities, 2013). Develop maps at the scale of 1:4000 and map hazard/ risk-wise vulnerable zones.
- Preparation of large-scale maps (1:10,000/1: 15,000) of areas vulnerable to floods with contours at an interval of 0.3 m or 0.5 m. (NDMA)
- Hazard inventory needs to be developed to analyze its impact 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.
- Regular updation of disaster database for future reference. Disaster communication systems need to be strengthened so that at the onset of disasters the early warning about the disaster can reach all the citizens of the city well in advance.
- Drainage mapping along the Landslide zone to record the change in the course over the period along with the catchment areas of streams and jhoras.
- Controlling water on roads and hill slopes – Water harvesting, roadside drainage, and cross drainage check dams.
- As mapping the hazard/disaster vulnerability and hazard susceptible zones across the city of Gangtok is being carried out at state and city level by various organizations and authorities like Sikkim State Disaster Management Authority, Land and Revenue Department, Geological Survey of India, Gangtok, SCA Himalayas, and DST CC, it becomes necessary to integrate such data and develop a common database and present the same at the common platform for the use of related departments and community at large. Along with a common database, updation of the same (metrological data), meteorological and hazard inventory, is required.

5.2.2 Slope Landscaping

- Installation of sustainable structural measures such as retaining wall. Adaption for the most durable type of retaining walls- Banded Dry-stone masonry or Cement masonry, Gabion, or retaining earth (NIDM Guidelines). Temporary slope retaining measures - Sandbag retaining wall, Precast concrete wall, sheet piles made of steel or timber, empty bitumen drum can also be used.
- Promoting afforestation activities and indigenous soil conservation techniques and growing of native plants with strong, deep root systems plantations along jhoras and nalahs.
- Landscape treatments such as vertical greening, screen planting, and toe planters. The use of Soil Improvement techniques is necessary to abate erosion along the slopes.

5.2.3 Early Warning System

- Need to install all-in-one early warning systems in the highly disaster vulnerable area for early evacuation.
- Early Warning systems for floods and landslides should be set up to coordinate and facilitate pre and post-disaster operations. Early Warning Systems should be the functional component of the City Disaster Management Plan.
- Installing instrumentation and slope monitoring for real-time early warning. For instance, Landslide Early-Warning System (LEWS) (NIDM Guidelines) needs to be installed.
- Developing regional Flood Information system – based on HKH Hydrological Cycle Observing System (HYCOS) as per the guidelines of WMO and monitoring, warning, and response systems (MWRS).
- Generating Flood Outlooks (NOAA (http://www.cnrfc.NOAA.gov/flood_outlook.php), regional flood outlook provides real-time flood information about the threat of potential large-scale flooding, forecasting, and warning services.
- Rainfall being the major cause of Gangtok Landslides - rainy seasons need to be monitored closely, with concerned localities need to be informed through the early warning system.

- Rehabilitation and stabilization of landslides affected sites along with the development of local expertise for early monitoring of ground instability.

5.3 Administration and Governance

- Defining role and responsibility of the Government and local bodies, public sector, NGOs, communities, and people at large before, during, and after a disaster.
- Training of first responders in search, rescue, and medicare. Training for visual and print media in the science and art of landslide management.
- 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 hazard/disaster 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 in some cases, in both the cities are needed for consolidated Database Management System (DBMS) for effective and efficient planning.
- The current role of city ULB is limited in disaster management activities within the city. 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 the capacities of all key stakeholders.
- The Emergency Operation Centres (EOCs) should be equipped with the necessary types of equipment and the latest technology. Well trained staff in EOCs, which should be located in safe zones to avoid a halt in its functioning during floods
- Developing and enhancing awareness among the community, mobilizing Local recourses expertise along with Public information and education system development. Sharing of virtual mapping and similar techniques can be considered for the dissemination of data and disaster management strategies at the community level.
- Along with the community, it's essential to work towards capacity building of the Urban Local Body officials and on-ground implementation of the Action Plan,

with the provisions of ward level community and basic infrastructure to mitigate disasters.

5.4 Socio-Economic

- A Slum rehabilitation plan should be developed to protect the most vulnerable, which usually encroach low lying disaster-prone areas of the city. Rehabilitation and provision of Shelters for poor people living in the landslide-prone and flood-prone areas is needed.
- Increasing public awareness and education is the key to cultural practices of safety. Awareness regarding proper land use as well as sustainable land management needs to be provided.
- Gender wise segregation of the data on migrant population which is the floating population of the city should be captured too.

Table 4: Roles and Responsibilities of Implementing Agencies

Indian Meteorological Department & Geographical Survey of India	• Weather forecasting and disseminating weather information • Geomorphology and Soil mapping, • Provision of Information to Urban Local Bodies on extreme weather events • Warning and early warning system set-up and updation of information
Department of Land Revenue and Disaster Management - Sikkim State Disaster Management Authority (SSDMA)	• 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 Gangtok

- 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
- Nallah and streams channel improvement, catchment-wide interventions and related structural measures for flood mitigation

Urban Development & Housing Department, Govt. of Sikkim

- Construction and maintenance of buildings (residential & non- residential)
- Amendment of building bye-laws
- Work in close collaboration with state govt. and Urban Local Bodies (ULBs) in terms of urban development and implementing housing schemes
- Assisting and guiding ULBs in terms of its functioning and execution of duties

Public Health Engineering Department, Sikkim

- 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 effluent and the water treatment plants

District Disaster Management Authority

- Search & rescue operation
- Relief & rehabilitation
- Traffic management during hazards
- Provides required guidance and corporates with the urban local bodies during disaster and disaster mitigation

Ward Level Disaster Management Committees

- Review and Analysis of ward level hazard vulnerabilities
- Work in coordination with District Disaster Management Authority (DDMA)

Urban Local Bodies: Gangtok Municipal Corporation

- Sanitation and Solid Waste Management
- Drainage mapping and planning of stormwater drainage system and sewerage network
- Relief & Rehabilitation of City slums/Urban poor
- Clearing of Jhoras/streams/nallahs
- Perform other duties relating to Disaster Management as assigned by the Disaster Management Authority

Though the NE region as a whole is expected to see an increase in average annual rainfall in 2030 with respect to 1970; Sikkim is expected to experience a decrease in precipitation of about 3% in 2030 with respect to 1970 (INCCA, 2010; State Action Plan on Climate Change for Sikkim, 2011). In the 2030s, the average annual temperatures are projected to rise by 1.8 to 2.1°C with respect to the 1970s (State Action Plan on Climate Change for Sikkim, 2011). For the 2050s, the average maximum temperature in Sikkim is expected to increase by 1.8-2.6°C 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 the risk of earthquakes, thunderstorms/ lightning, forest fires, and water scarcity.

Along with the climate changes, increased urban population, from 17% (2001) to over 271% (2011), and urban space development has increased population exposure to disasters and their direct and indirect impact. In addition to the urban population, the floating population has increased over the period, with increased tourists' inflows and slum population (31%). These vulnerable populations are at high risk and require indiscriminate basic services and its proper management.

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. The urban vulnerability assessment indicated a huge risk incurred due to current building practices, with the building bye-laws (Sikkim Building Construction (Amendment) Regulations, 2000) not updated and lacking in need-based development. There is a need to adopt indigenous material/nature-based solutions and bio-engineering techniques for construction purposes. The existing critical infrastructure needs to be mapped at the ward level and heritage buildings need to be restored and conserved, which proper structural inspection at regular intervals. The existing physical and socio-economic infrastructure is unable to cater to basic urban requirements. The city immediately needs a sewerage treatment plant and control the dumping of solid waste in johras.

For Hazard Management, hazard zonation mapping is essential with updated hazard inventories and impact assessment. There is a need to update the existing Landslide Early warning system and procure a Flood Early warning system. An all-in-one early warning system in the highly disaster vulnerable area for early evacuation programs

are recommended. Rehabilitation and stabilization of landslides affected sites by slope landscaping, installation of sustainable structural measures, and promoting afforestation activities and indigenous soil conservation techniques. A consolidated Database Management System (DBMS), needs to be established along with defining the roles and responsibilities of the urban local bodies. Slums pockets and population distribution needs to be mapped and a rehabilitation plan should be made to protect the most vulnerable.

Over the decades the Sikkim State Disaster Management Authority (SSDMA) has developed and updated the Disaster Management Plans, East Sikkim (2020-21, 2018-19), describing specifically various aspects of disaster management at the state and city level while mapping the vulnerability of the people to hazard. Multi-Hazard Rapid Vulnerability Assessment (MHRVA), 2012 and 2018 (by SSDMA and land Revenue & Disaster Management Dept. Govt. Sikkim) has also been prepared to enhance the disaster preparedness for effective response and to 'Build Back Better' in investment in DRR and Recovery, Rehabilitation and Reconstruction. Susceptibility/vulnerability maps are developed for hazards like Drought, Earthquake, Fire, Flash flood, Landslides, Hailstones & Snow/Avalanches at the scale of 1: 25,000 and 1: 10,000. SSDMA and Gangtok Municipal Corporation (GMC), has also prepared Gangtok City Disaster Management Plan (CDMP) (Evacuation and Response), 2015, focusing on the disaster response and evacuation activities.

A Disaster Resilience Action Plan is required for the city, with ward-wise mitigation and adaption plans with local ward level committee being set up to ensure adequate community participation. Detailed maps at ward level scale should be developed mapping the hazard susceptibility (landslides, flash floods, and earthquakes) zones, and existing critical infrastructure. Hazard Vulnerability mapping is an integral part of drafting a disaster resilience action plan for any city, which can be replicated and used for developing short-medium-long term structural and non-structural resilience action strategies/measures for other Himalayan cities along the Himalayan regions.

Some of the existing programs and schemes at the city and state level wherein the Disaster Resilience palling can be incorporated in the Urban Development:

- **AMRUT –** hazard vulnerability assessment can be used to map existing status and gaps in the urban basic and critical infrastructure and develop strategies to strengthen the disaster resilient infrastructure, like wastewater treatment plans,

covered drains, restricted dumping of solid waste into natural streams, increasing stormwater drainage networks likewise.

- **Housing for All –** Socio-economic vulnerability assessment, can help in mapping the urban vulnerable sections while delineating hazard-prone areas for proper rehabilitation. This will also help in adopting and encouraging traditional knowledge in the construction of hazard resilient houses.
- **Smart City Mission –** the vulnerability assessment can aid in amending building bye-laws to ensure structural safety and include bio-engineering and nature-based solutions for slope –landscaping, and construction disaster-resilient infrastructures. This will also include Training and Capacity Building of the ULB officials and the first responders (community) to mitigate disasters.

Thus the vulnerability assessment will not only help in mapping the existing physical and socio-economic vulnerability needs of the city but also help in framing a detailed implementation framework to strengthen the governance and administrative structure of the city while procuring and strengthening the early warning systems and preparedness methodology for improved risk management.

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References

1. Kundu, A. (2012). Flash Flood kills 22 in Sikkim. Retrieved from Times of India):. http://timesofindia.indiatimes.com/india/Flash-flood-kills-22-in-Sikkim/articleshow/16509127.cms
2. AMRUT. (2017-18). State Annual Action Plan.
3. Anbalagan. (1993). Environmental Hazards of Unplanned Urbanization of Mountainous Terrains: A Case Study of A Himalayan Town. Quarterly Journal of Engineering Geology 26, 179-184.
4. David Eckstein et al. (2020). Global Climate Risk Index 2020. Berlin: Germanwatch.
5. Eckstein D. et al. (2019). Global Climate Risk Index. Berline: Germanwatch.
6. EM-DAT. (2019). The OFDA/CRED International Disaster Database. EM_DAT.
7. ENVIS. (2018). ENVIS. Retrieved from The Himalayas: http://gbpihedenvis.nic.in/indian_him_reg.htm
8. Gangtok Municipal Corporation. (2020). City Profile. Retrieved from Gangtok Municipal Corporation: http://www.gmcsikkim.in/index.php/only-home/8-hidden-module/12-city-profile
9. Garschagen, M. (2016). Decentralizing Urban Disaster Risk Management in a centralized system. . Habitat International, 43-49.
10. ICLEI South Asia. (2020). City Biodiversity Index of Gangtok. Prepared under the BMU supported INTERACTBio project
11. J. Parikh, et al. (2015). Sustainable and Disaster Resilient Urban Development, Report Series on 10 cities. India: IRADe, New Delhi.
12. Jyoti Parikh et al. (2014). Vulnerability Profiling of Cities - A framework for Climate-resilient urban development in India. Asian Cities Resilience- Working Paper Series 8.
13. Khadka, N. S. (2021). BBC World Service. Retrieved from The Himalayan hazards nobody is monitoring: https://www.bbc.com/news/world-asia-india-56247945
14. NDMA. (2019). National Disaster Management Authority. Retrieved from Vulnerability Profile of India: https://ndma.gov.in/en/vulnerability-profile.html
15. NIUA. (2016). Implementation of Multi-Level Car Parking cum Commercial Development at Old West Point School Area. New Delhi: Smart City.
16. R. Magotra, et. al. (2019). Sustainable and Disaster Resilient Urban Development - Assessment of 10 cities in India. India: IRADe, Delhi.
17. Sanderson, D. (2000). Cities, Disasters, and Livelihood. Environment and Urbanization, 12(2), 93-102.
18. SPCB, Sikkim. (2020-21). Municipal Solid Waste Management, Annual Report. Gangtok: SPCB, Sikkim.
19. SSDMA & GMC. (2015). City Disaster Management. SSDMA & GMC.
20. SSDMA. (2012). Multi-Hazard Risk Vulnerability Assessment. Gangtok: SSDMA.
21. UNISDR, WHO. (2008). International Strategy for Disaster Reduction. UNISDR, WHO.
22. UDHD, Govt of Sikkim. (2017) City Development Plan
23. Walker, B. (2011). Urban Peaks in the Himalayas. China Dialogue. Retrieved from https://www.chinadialogue.net/article/show/single/en/4306- Urban-peaks-in-the-Himalayas
24. Wilkinson, E. (. (2012). Why 'Small is Beautiful' in Municipal Disaster Risk Reduction. . Environmental Hazards, 155-171.