Design and Application of a Multi-Hazard Risk Rapid Assessment Questionnaire for Hill Communities in the Indian Himalayan Region

Shivani Chouhan[1*], Mahua Mukherjee[2]

[1]Research Scholar, Centre of Excellence in Disaster Mitigation and Management, Indian Institute of Technology Roorkee, Roorkee, India
[2]Professor, Centre of Excellence in Disaster Mitigation and Management, Indian Institute of Technology Roorkee, Roorkee, India

*Corresponding Author: Shivani Chouhan (*s_chouhan@dm.iitr.ac.in)*

*__Corresponding Author:__

Name: Ms. Shivani Chouhan,
Email: *s_chouhan@dm.iitr.ac.in,*
Telephone: +91-9675457229 , +49-1744969778
Postal Address: Centre of excellence in disaster mitigation and management, IIT Roorkee, Roorkee Uttarakhand, 247667, India

ABSTRACT

The Indian Himalayan Region (IHR) is prone to multiple-hazards and suffers great loss of life and damage to infrastructure and property every year. Poor engineering construction, unplanned and unregulated development, and relatively low awareness and capacity in communities for supporting disaster risk mitigation is directly and indirectly contributing to the risk and severity of disasters.

A comprehensive review of various existing survey forms for Risk assessment has found that the survey questionnaires themselves have not been designed or optimised, specifically, for hill communities. Hill communities are distinctly different from low-land communities, with distinct characteristics and susceptibility to specific hazard and risk scenarios. Previous studies have, on the whole, underrepresented the specific characteristics of hill communities, and the increasing threat of natural disasters in the IHR creates an imperative to design hill-specific questionnaires for multi-hazards risk assessment.

The main objective of this study is to design and apply a hill-specific risk assessment survey form that contains more accurate information for hill communities and hill-based infrastructure and allows for the surveys to be completed efficiently and in less time. The proposed survey form is described herein and is validated through a pilot survey at several locations in the hills of Uttarakhand, India. The survey form covers data related to vulnerability from Earthquake (Rapid Visual Screening), Flood, High Wind, Landslide, Industrial, Fire Hazard in the building, Climate Change and Non-Structural Falling Hazard. The proposed form is self-explanatory,

pictorial with easy terminologies, and is divided into various sections for better understanding of the surveyor etc.

The application process confirmed that the survey questionnaire performed well and met expectations in its application. The form is readily transferrable to other locations in the IHR and could be internationalised and used throughout the Himalaya.

Keywords: Survey, Questionnaire Design, Multi-Hazard, Rapid Visual Screening, Himalaya

1 Introduction

The Indian Himalayas considered a significant part of the world's mountain ecosystems (Singh, 2005). The Himalayas are geologically active, delicate, and vulnerable to both natural and human-made processes due to their structural instability and maturity (Kala, 2014). Numerous hazards interact at most locations, resulting in cascading or synergetic effects (Aksha *et al.*, 2020). The Indian Himalayan Region (IHR), being prone to multiple hazards, suffers great loss of life and damage to infrastructure and properties every year (Chouhan et al.,2022a). Multi-hazard frequency has risen in recent decades, resulting in massive socio-economic losses. There has been a constant rise in the number of deaths, property losses, and damage to infrastructure and facilities (Chandel and Brar, 2010). According to UNDRR (UNDRR, n.d.), the multi-hazard concept refers to “(1) the selection of multiple major hazards that the country faces, and (2) the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects.”

Poor engineering and construction, reckless development, human intervention, unrecognized practices, irresponsible development initiatives, and a lack of knowledge are directly and indirectly contributing to the risk and severity of disasters (Chouhan et al., 2022b). Many natural disasters have become human-made phenomena as a result of the spread of irresponsible construction practices. Such disasters have a devastating socio-economic impact on the country's economy, putting even more strain on an already stressed economy (Disasters, 2007).

Various research work, disaster risk assessment studies and, implementation projects are being executed by national and international organizations for disaster risk reduction in the Himalayas. The data collection for any risk assessment in this difficult terrain is a crucial task, as correct information documentation has played a significant role that directly or indirectly lead to an influence in correct assessment of the risk factor (Chouhan et al.2022b).

Surveys using a well-crafted questionnaire is a proven method in the research fraternity. Questionnaires are the backbone of every survey when it comes to data collection. Using data, one can gain a detailed understanding of a community's hazard profile, vulnerability interactions and their contribution to risk reduction (Buck and Summers, 2020). The survey information is required to be coherent for data analysis since they lead to critical decisions at many levels, represent the site's vital characters and society's expectations and requirements too. All of these outcomes hinge, of course, on the creation of a robust site-specific survey form. A well designed and executed Multi-Hazard Risk Assessment (MHRA) can lead to more robust strategies for disaster risk reduction (Kala, 2014; Sekhri et al., 2020) and can facilitate by prioritizing development planning decisions.

After studying existing survey forms and practical field survey at various locations in the Indian Himalayas, authors found that the existing MHRA survey forms used in India have some lacuna from the hills point of views as Himalayas have different geography, cultural, development practices, hazard profile etc. (Chouhan et. al., 2022b). A close evaluation of the existing survey questionnaires reveals that there is a need for IHR-specific survey questionnaire form to facilitate a MHRA, which should be easy to understand, pictorial, and that creates a two-way disaster sensitization of giving and getting information from the community.

In this research paper, the journey to design and application of the proposed Hill specific MHRA survey form has been described. The pilot survey using the proposed survey form has been conducted at 10 schools in Uttarakhand state of India and its results identify various risk indicators in individual building as well as the school campus.

2 Background

2.1 Defining the Indian Himalayan Region

The Indian Himalayan Region (IHR) straddles the northern latitudes of 26 20′ and 35 40′, and the eastern latitudes of 74 50′ and 95 40′ (Sekhri et al., 2020). In India, it comprises 16.2 % of all the geographical land and is home to 76 million people. Natural resources, biodiversity, and ethnic variety are abundant in IHR. (Goodrich et al., 2019; Sekhri et al., 2020). It stretches from the Indus River to the Brahmaputra River in the east. (Srivastava et al., 2015). There are a total of 11 Indian Himalayan states and 2 Union territories as shown in Fig. 1, which have 109 administrative districts (Kala, 2014). The region is socially and economically underprivileged, with 171 schedule tribes accounting for almost 30 % of India's total tribal population and a high literacy rate of 79 percent. The population is growing exponentially, putting a strain on the region's resources (COI, 2011). Tourism is a lucrative business in IHR (NITI Aayog, 2018) and it contributes to support a lot of construction projects like hotels, restaurants, road construction etc. across the region (Kala, 2014). Agriculture is a profitable venture for Himalayan people, and it is mainly rain-nourished. Furthermore, climate change is hazardous to the region's progress and hinders socio-economic development (Sekhri *et al.*, 2020).

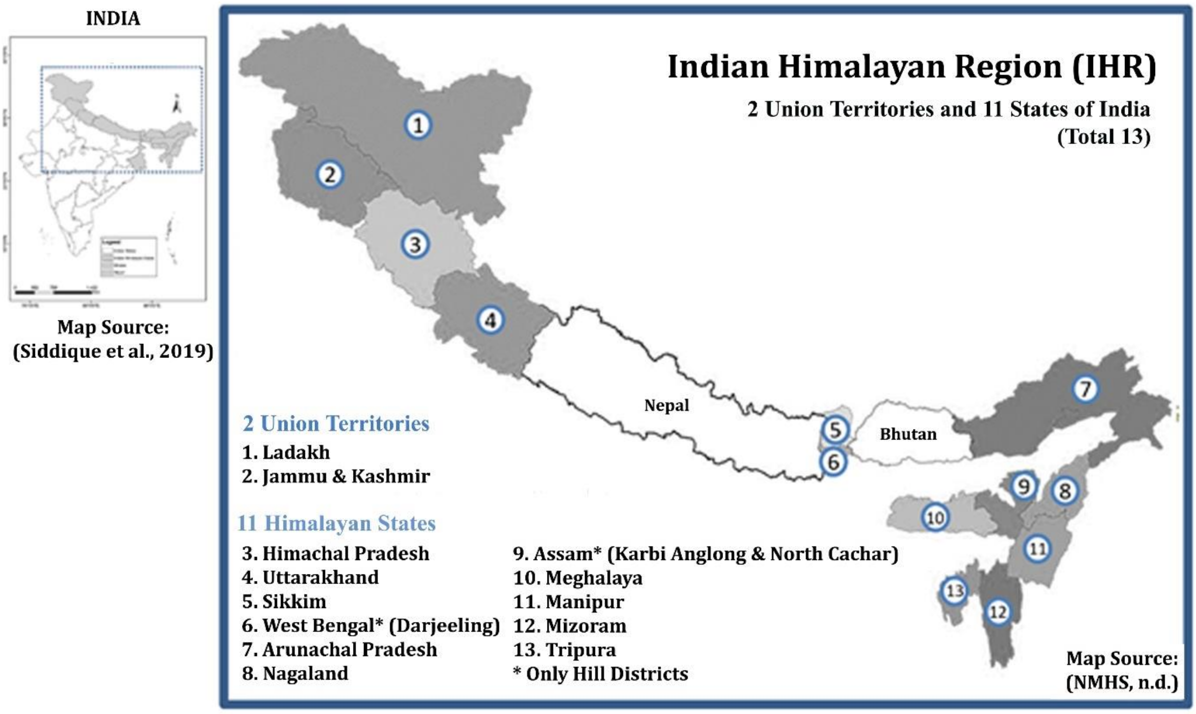


Figure 1: Study Area: Indian Himalayan Region, Source: adapted from (NMHS, n.d.)(Siddique et. al., 2019)

The IHR represents a significant role in the world's mountain ecosystems (Singh, 2005). IHR attracts tourists worldwide because of its natural richness, unique biodiversity, and cultural diversity (NITI Aayog, 2018,; Gaur and Kutro, 2018). The number of pilgrims has risen dramatically in prominent pilgrim centres across the Himalayas over the ages (Kala, 2014), putting extra stress on these resources and posing a danger of socioeconomic loss.

2.2 Multi Hazards in IHR

Being geologically young and expanding (Wester et al., 2019), the IHR is vulnerable to natural disasters (Gautam et. al., 2013). The Himalaya, the world's highest mountain range is geologically active, fragile, and susceptible to natural and man-made processes (Kala, 2014). Indian geography, climate, topography, and population growth all contribute to its high risk and vulnerability (Sharma *et al.*, 2017). Mountain hazards are widespread, and hills characteristics of fragility, restricted accessibility, marginality, and heterogeneity (Gerlitz et al., 2016) may turn a hazard into a catastrophe, transforming mountains into high-risk zones. Furthermore, mountains need a long time to recover from disruptions (Sekhri *et al.*, 2020).

Multi-Hazard Frequency has risen in recent decades, resulting in massive socio-economic losses (Rehman et al., 2022). Unrecognized practices, irresponsible development initiatives, and a lack of knowledge contribute to disasters having a more significant effect. One of the most challenging aspects of natural hazards risk assessment is determining how to estimate the risk of several hazards in the same region and how they interact (Hackl et. at., 2015).

In the recent decade, severe earthquakes, floods, and landslides have devastated IHR, including the M 7.6 Kashmir earthquake in 2005, the Malpa Landslide in 2009, the M 6.8 Sikkim earthquake in 2011, the 2013 Uttarakhand flash flood, and others, affecting approximately thousands of deaths and property losses (MHA, 2011; BMTPC, 2019; Kumar et al., 2016). Table 1 illustrate and describe the major hazard events that have occurred historically in the Indian Himalayan region.

Table 1: Major Disaster Events in IHR, Source: adapted from (BMTPC, 2019; Kumar et al., 2016).

SN	**Date**	**Location** (Latitude, Longitude)	**Place**	**Indian Himalayan State**	**Hazard/ Magnitude**	**Casualties**	**Source**
1	1869, Jan 10	(25.00, 93.00)	Near Cachar	Assam	Earthquake 7.5 Mw	Unknown	Kumar et al., 2016
2	1885 May 30	(34.10, 74.60)	Sopor	Jammu & Kashmir	Earthquake 7.0 Mw	Unknown	Kumar et al., 2017
3	1897 Jun 12	(26.00, 91.00)	Shillong plateau	Meghalaya	Earthquake 8.7 Mw	1500	Kumar et al., 2018
4	1905 Apr 04	(32.30, 76.30)	Kangra	Himachal Pradesh	Earthquake 8.0 Mw	19,000	Kumar et al., 2019
5	1918 Jul 08	(24.50, 91.00)	Srimangal	Assam	Earthquake 7.6 Mw	Unknown	Kumar et al., 2020
6	1930 Jul 02	(25.80, 90.20)	Dhubri	Assam	Earthquake 7.1 Mw	Unknown	Kumar et al., 2021
7	1943 Oct 23	(26.80, 94.00)	Assam	Assam	Earthquake 7.2 Mw	Unknown	Kumar et al., 2022
8	1950 Aug 15	(28.50, 96.70)	Arunachal Pradesh–China Border	Arunachal Pradesh	Earthquake 8.5 Mw	1526	Kumar et al., 2023
9	1975 Jan 19	(32.38, 78.49)	Kinnaur	Himachal Pradesh	Earthquake 6.2 Mw	Unknown	Kumar et al., 2024
10	1988 Aug 06	(25.13, 95.15)	Manipur–Myanmar border	Manipur	Earthquake 6.6 Mw	1000	Kumar et al., 2025
11	1991 Oct 20	(30.75, 78.86)	Uttarkashi, UP	Uttarakhand (now)	Earthquake 6.6 Mw	2000	Kumar et al., 2026
12	1998 Aug 18	(30.01, 80.04)	Malpa, Pithoragarh district	Uttarakhand (now)	Landslide	380	Kumar et al., 2027
13	1999 Mar 29th	(30.41, 79.42)	Chamoli District, UP	Uttarakhand (now)	Earthquake 6.8 Mw	100	Kumar et al., 2028
14	2005 Oct 08th	(34.48, 73.61)	Kashmir	Jammu & Kashmir	Earthquake 7.6 Mw	74,500	Kumar et al., 2029
15	2006 Feb 14th	(27.37, 88.36)	Sikkim	Sikkim	Earthquake 5.7 Mw	0	BMTPC, 2019
16	2010 Aug 06th	(34.15, 77.57)	Leh	Ladakh (now)	Cloudburst	257	BMTPC, 2019
17	2011 Sep 18th	(27.7, 88.2)	Sikkim Nepal border	Sikkim	Earthquake 6.8 Mw	60	Kumar et al., 2016
18	2012 July-Aug	(26.20, 92.93)	Assam	Assam	Floods	91	BMTPC, 2019

19	2012 Aug-Sep	(30.72, 78.43), (30.28, 78.98), (29.84, 79.76)	Uttarkashi, Rudraprayag & Bageshwar	Uttarakhand	Floods	52	BMTPC, 2019
20	2013 June 16th	(30.06, 79.01)	Uttaranchal	Uttarakhand (now)	Flood, Landslide, Cloud Burst	5748	Kumar et al., 2016
21	2014 Sep	(33.27, 75.34)	Jammu & Kashmir	Jammu & Kashmir	Flood, Cloud Burst	277	Kumar et al., 2016
22	2016 Jan 04th	(24.81, 93.93)	Imphal, Manipur	Manipur	Earthquake 6.7 Mw	8	BMTPC, 2019

The Himalayan region is among the most seismically active in the world due to the collision of the Indian and Eurasian plates. A series of four major earthquakes has occurred within a short span of 53 years (Srivastava et al., 2015); namely Shillong (1897), Kangra (1905), Bihar-Nepal (1934) and Assam-Tibet (1950). Tectonic activities in the mountains constantly threaten the stability of the mountains, being an active region. One of the most frequent natural disasters in the Himalayas occurs when large landslides occur, destroying infrastructures, destroying trees, and killing people. Landslides cause huge social and economic losses to mountain-dwelling populations.(Sarkar et al., 2015). The areas which are close to the River valley has witnessed a large number of mass movements during recent years (Srivastava et al., 2010). A recent flash flood, along with a debris flow at Kedarnath on 16-17 June 2013, which claimed over a thousand lives, was caused by cloudbursts and landslides breaching temporary dams along river valleys (Allen, 2015). More than 82 percent of the world's population lived on land affected by floods between 1985 and 2003 (Mouri *et al.*, 2013). There is an increase in forest fire frequency globally, especially in Asia. There are major environmental and ecological impacts caused by wildfires, which can result in the fatalities of tens of thousands of people and massive property losses (Parajuli et al., 2020).

2.3 Need of Study

Without a comprehensive evaluation of multi-hazards, it is impossible to develop any concrete policy measures to combat the potential risk posed by multiple hazards.(Sekhri et al., 2020) IHR being prone to Multi Hazards (Kala, 2014), Risk Resilient Development planning is the only way to prepare Himalayan community from upcoming disasters.

It is well known that the Himalayas are a high-risk area for multi-hazards (Pathak et al., 2019), although fewer risk assessments have been conducted in the IHR region. An assessment of hazards generally focuses on a single threat, such as landslides, earthquakes, or flooding. As a result, physical processes are considered in isolation. In most areas of the Himalayas, hazards are interrelated and generate cascading effects or synergies which make the entire region vulnerable (Sekhri et al., 2020). Probabilistic risk frameworks have been proposed, but as a result of a lack of quality and quantity of data, these approaches are seldom feasible in developing countries (Sanam et al., 2020). Furthermore, the existing risk assessment models/tools for a specific hazard in the region has limited application and effectiveness from a policy standpoint (Sekhri et al., 2020).

Researchers are involved in a number of research projects in IHR in the field of assessing the risk of disasters in India, though there have been very few assessments of hazards associated with the IHR region, none of which incorporate multi-hazards (Wester et al., 2019) In addition, risk resulting from a single hazard is not applicable and cannot be considered effectively in policy analysis in the region (Sekhri et al., 2020).

The comparative study of some of the most used survey forms to assess risk in India is shown in the Table 2. Every survey form has its own unique features. In some cases, the focus is largely on one particular hazard and the other hazards are minor. The detail of all the mentioned survey forms will be explained later in Table 4 in this paper. It has been observed from the Table 2 that none of the forms (SN 1 to 6) are focusing on Multi Hazard Risk calculation/identification as per IHR Scenarios, which is not only prone to earthquakes, but also prone to floods, landslides, high winds, industrial hazards and at building level falling hazard (Non-Structural Hazard), fire and electrical hazards etc.

Table 2: Comparison between survey forms used in India to assess Risk

Comparative Study between some survey forms used in India								
SN		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Developed by/for		ARYA	FEMA	NDMA	IIT-B	HPSDMA	BMTPC	MH-RVS (Proposed)
Source: adapted from		Arya, 2006	FEMA , 2015	NDMA , 2020	Sinha & Goyal, 2001	Kumar et al., 2016	BMTPC , 2019	Author
Understanding	Pictorial					□		□
IHR is prone to Multi Hazard	Earthquake	□	□	□	□	□	□	□
	Flood			□		□	□	□
	High Wind						□	□
	Landslide	□	□	□		□	□	□
	Fire and Electrical					□		□
	Industrial							□
	Climate Change							□
	Non-Structural /Falling Hazard	□	□	□	□	□		□

Furthermore, while working with data collection teams on the ground during DRR Projects, the authors have observed that surveyors face several problems, such as the technically advanced language of the existing survey form, which requires trained technical personnel to fill out, and this leads to costly human resources. Secondly, no graphical explanation of the form leads to understanding, which further leads to incorrect data collection. Thirdly, Surveyors are not able to convey correct objective to the respondent, creates no interest to response to reply further. Fourthly, most of the above-mentioned forms are not hill specific. MHRA survey forms need to be made easy, simple, informative, with simple language or/and visual explanation, for surveyors as well as respondents to get connected to it for giving and receiving information.

Indian Himalayan Region is also the point of attraction for tourists and pilgrims globally, and tourism plays an imperative role in enhancing the economy of the Himalayan state. Thus, safety is the immense need of the government at various levels.

There is no such survey form for comprehensive database for the IHR Region for informed decision-making, related to multi hazard and other aspects of sustainable hill development. Considering the IHR scenarios, there is immense need for a Hill specific survey form, that can help to gather important information from the field and help in Risk assessment for further decision making, to prepare the hill community from future disasters.

3 Multi Hazard Survey Framework

3.1 Survey Form design methodology

The survey methodologies start with a few recommendations for designing a good survey, like (1) the survey form should satisfy the objectives of the research, (2) there should appropriate (but not very long) length of questionnaires coving all essential parts, (3) questions should convey a single thought at a time, (4) language should be simple and easy to understand by the surveyors as well as the respondent, (5) multiple choice questions are mostly preferred to increase response rate, reduce time and patterned the responses, (6) The survey should be concrete and conform to the respondent's perspective, (7) the use of unclear words should be avoided (8) it should meet the survey logic i.e. there is no further progress or possibility of further correspondence from the respondent, if the logic is flawed. It takes practice and verification to ensure that when considering an option only the next logical question comes to mind (Roopa and Rani, 2012).

3.2 Methodology Adopted

To gather beneficial and appropriate information related to multi-hazards in the Himalayan region, careful attention must be given to the design of the questionnaire that covers all the important contributing factors from various identified hazards and fulfils all the gaps identified from the existing survey form and field experience. Designing an effective questionnaire, it takes time, effort, and a variety of stages. The methodology to prepare the Multi-Hazard Survey form for Indian Himalayan Region is shown in Fig. 2.

A number of Disaster Risk Reduction projects conducted in Indian Himalayan Region provided Author 1 with a rare opportunity to be part of a Data Collection team. As a result of these projects, author has been able to interact on the ground with hill communities and surveyors and learned that there are several gaps in the existing survey forms (Section 3.4) from both a Himalayan and surveyor perspective. MHRA Survey form contains all the gist of data collection experience. This research paper is based on a comprehensive literature review (Section 3.3) as well as field experience.

To ensure that the survey form was designed in accordance with Disaster Risk Assessment requirements, Hill specific hazards, important components, question sequence and layout, simple language, disaster sensitization, and two-way information sharing (giving and receiving), some initial considerations were taken into account.

We have designed a draft MHRA survey form (Section 4.1) and applied it to some of the buildings in five villages in Uttarakhand (Fig. 5). An initial pilot survey has been conducted at 10 schools (section 4.2) using the proposed survey form with content and graphical inputs. The results and observations relating to the Pilot survey are discussed in sections 4.2 and 4.5 of this paper.

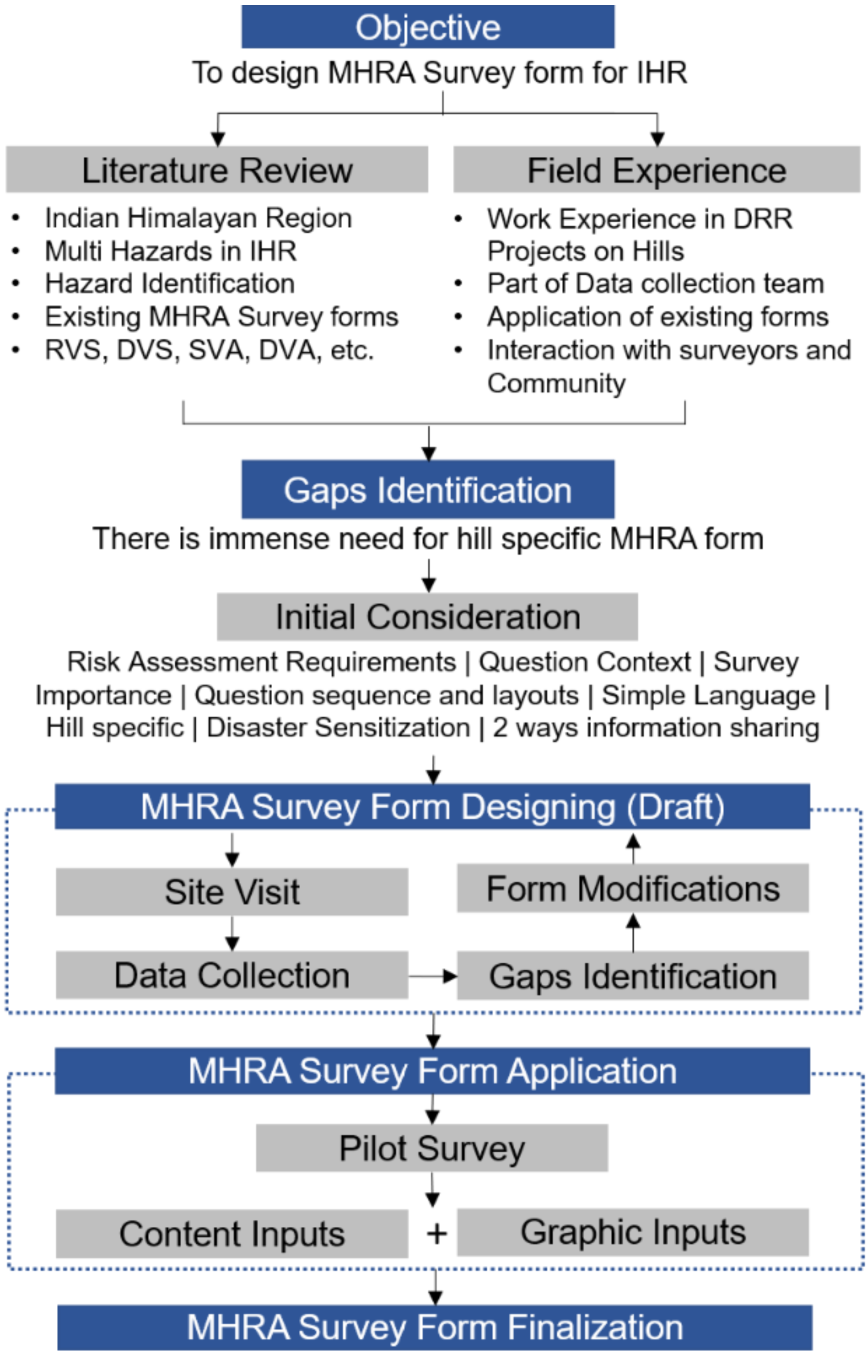


Figure 2: Methodology adopted by author

3.3 Existing Multi Hazard Risk Assessment (MHRA) Survey Forms

The spread of non-engineering construction, unrecognized construction and planning practices, reckless developmental activities, and a lack of awareness increase the impact of disasters. IHR being seismically active, as shown in the seismic zonation map of India, creates the importance of Risk assessment of existing buildings. Earthquakes are feared because they are so unpredictable. Yet, as we often hear, "Earthquakes don't kill, Buildings do" (attributed to Francesca Valli, Change Management Thought-Leader), and as the detailed assessment is limited by the number of homes and the cost, one of the considering approaches is Rapid Visual Screening (RVS) that is used for seismic vulnerability assessment. Using this methodology, a risk assessment has been conducted for areas subjected to earthquakes (Kumar et al., 2016).

3.3.1 Seismic Zonation Map of India

The first seismic zoning map of India was published in 1935 by the Geological Survey of India (G. S. I.) (Fig. 3) (A. K. Mohapatra, 2010). Based on the damage earthquakes caused in various parts of India, this map has undergone numerous modifications (IS-code1893-1, 2002) (Marcussen, 2017), (Khattri *et al.*, 1984) since its original creation As per the Seismic zonation map, India is divided into four distinct seismic risk zones shown here by colour (Dunbar, 2003) in Fig. 3 below:

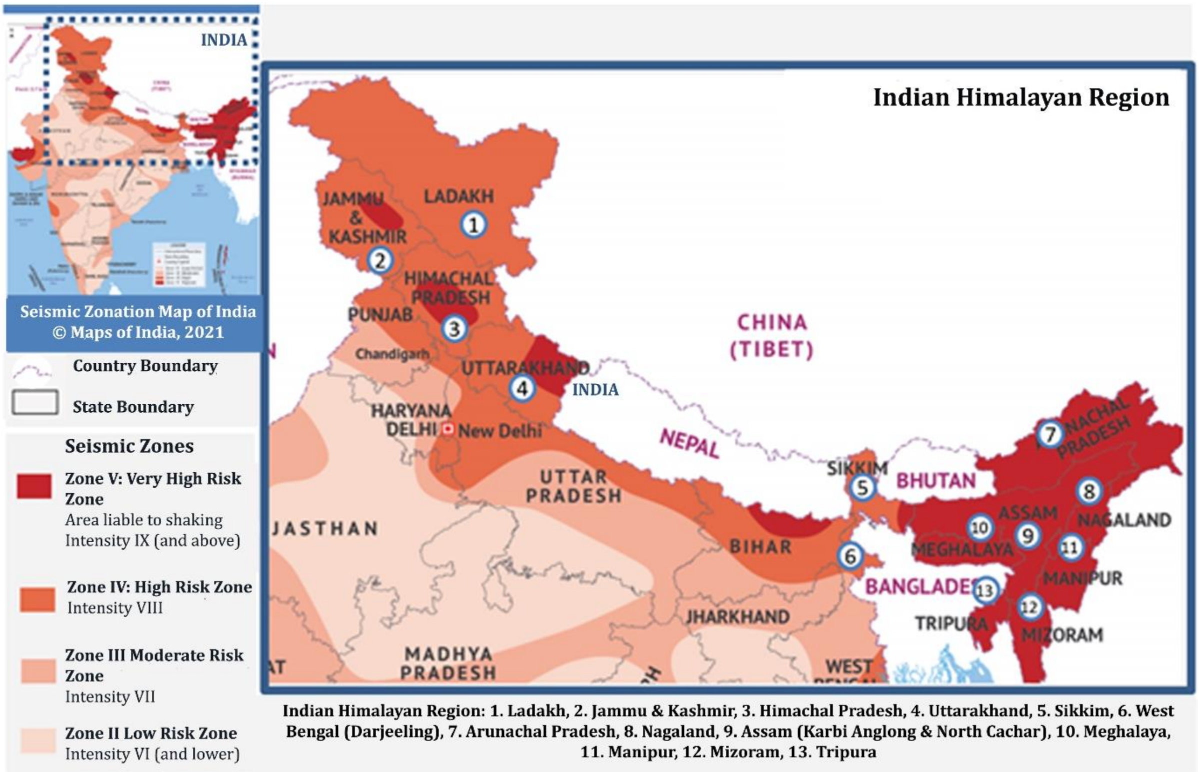


Figure 3: Seismic Zonation Map of India, Source: adapted from (pp. Map of India, 2021)

3.3.2 About RVS

Applied Technology Council (ATC) developed the RVS method in the late 1980s and published it in the FEMA: 154 in 1988. In later versions, it was revised in FEMA: 178-1989, 1992 (revised), FEMA: 310-1998, and FEMA: 154-1988, 2002 (revised), for rapid visual screening of buildings. (Kumar et al., 2016)

Rapid Visual Screening (RVS) avoids the need for structural calculations by using a visual method. An evaluator determines damageability grade by identifying (a) the primary structural lateral load resisting system as well as (b) the structural features of the building that can impact seismic performance in combination with that system. The process of inspecting, gathering data, and deciding on the next course of action occurs on site and may last several hours, depending on the size of the building (Arya, 2006; Arya, 2006b).

3.3.2.1 Uses of RVS Results:

The foremost uses of this technique concerning seismic advancement of existing buildings are to assess a building's seismic vulnerability to categorize it further. It is used to determine the structural vulnerability (damageability) of buildings and determine the seismic rehabilitation requirements. In cases where further assessments are not considered necessary or are not feasible, retrofitting requirements are simplified (to a collapse prevention level) (Arya, 2006a; Arya, 2006b).

3.3.3 Multi Hazard Risk Assessment used in India

3.3.3.1 RVS Methodology Proposed by Prof. Anand S Arya for Masonry Buildings

This RVS procedure that was designed for the Indian context follows a grading system where the screener identifies the primary load-resisting system of the building and determines parameters that may be modified to improve seismic performance of the structure (NDMA, 2020)

Rapid Visual Screening form of Masonry Buildings developed by Prof. Anand S Arya consist of zoning, according to Indian conditions, and buildings with importance are given consideration. Also, special hazards (liquefiable area, landslide prone area, plan irregularities, and vertical irregularities) and falling hazards are taken into account. Finally, a grading system was performed in the buildings. Refer (Arya, 2006a) for detailed RVS survey forms for masonry buildings.

3.3.3.2 RVS Methodology Proposed by Prof. Anand S Arya for RC frame or Steel Frame

The Rapid Visual Screening form of Reinforced Concrete frame and Steel Frame for Seismic Hazards developed by Prof. Anand S Arya has 6 components (i) general information (ii) Building typology based on foundation type, roof, floor, etc. (iii) Structural frame type (iv) Special Hazard (v) Non-Structural building components (vi) Damageable Grades (Arya, 2006b).

Seismic safety features of RC Frame Buildings consist of parameters like Frame Action, Presence of Soft Storey, Short Column Effect, Concept of Weak Beam Strong Column, Pounding of Buildings, Building Distress and Other important features, Water Seepage, Corrosion of Reinforcement, Quality of Construction, Quality of Concrete and non-structural falling hazards. Refer (Arya, 2006a; Arya, 2006b) for detailed RVS Survey form for RC and steel buildings.

3.3.3.3 RVS Procedure developed by Dr. Sudhir K Jain

In this method, a checklist for pre-screened buildings is prepared based on Indian conditions. It is one of the first methodologies in India featuring a points system. Performance scores are calculated based on factors such as zone, architectural considerations, structural parameters, and geotechnical characteristics. In India, this method is used in many locations, with the first applications being in Gujarat after the Bhuj earthquake (Jain et al., 2010).

3.3.3.4 RVS form developed by NDMA 2020

In the Disaster Management Act of 2005, a paradigm shift from Relief-centric approach to Mitigation- and Preparedness-centric approach is sought, with continued emphasis on proactive, holistic and integrated Response. With this Act in mind, NDMA initiated a series of discrete, comprehensive, and integrated initiatives. Among the recommended actions was assessing earthquake risk within the existing built environment.

NDMA developed this report to make end users aware of RVS's outcomes by presenting RVS in clear and tangible terms. On the basis of discussions with the relevant domain experts, NDMA have developed recommended forms for Pre-Earthquake and Post-Earthquake Level 1 Assessments of 7 building typologies (i. Reinforced Concrete Building, ii. Burnt Clay Bricks Building, iii. Confined Masonry Building, iv. Random Rubble Masonry Building, v. Mud House, vi. Dhajji Dewari, vii. Ekra House). A form is developed to categorize the different building attributes into three categories: Red (High Risk), Yellow (Moderate Risk), and Green (Low Risk) (NDMA, 2020).

3.3.3.5 Seismic Vulnerability Assessment by Prof. Ravi Sinha and Prof. Alok Goyal

Prof. Ravi Sinha and Prof. Alok Goyal from Indian Institute of Technology Bombay (IIT-B) prepared a "National Policy for Seismic Vulnerability Assessment of Buildings and Procedure for Rapid Visual Screening of Buildings for Potential Seismic Vulnerability". A key feature of this procedure is that it allows a trained evaluator to conduct a walkthrough of the building to determine vulnerability. It is compatible with GIS-based city databases, and can also be used for a variety of other planning and mitigation tasks (Sinha and Goyal, 2001).

RVS analysed 10 different types of building, based on the materials and construction types most commonly found in urban areas. There were both engineered and non-engineered constructions (built according to specifications) in this category (Sinha and Goyal, 2001).

3.3.3.6 Building Vulnerability form developed by HPSDMA & TARU

A form originally prepared by TARU consultancy and the Himachal Pradesh State Disaster Management Authority (HPSDMA) is shown in (Kumar et al., 2016). A building is visually examined by an experienced screener as part of RVS to identify features that contribute to seismic performance. This method is known as a 'sidewalk survey.' In this side walk survey, checklists are provided for each of the five types of buildings i.e., RC frames, brick masonry, stone masonry, Rammed Earth, and hybrid (Kumar et al., 2016).

3.3.3.7 Vulnerability Atlas of India developed by BMTPC

Building Materials and Technology Promotion Council (BMTPC) published the Vulnerability Atlas of India as its first edition in 1997 (BMTPC, 2019). It was hailed as "useful tool for policy planning on natural disaster prevention and preparedness, especially for housing and related infrastructures". First of its kind, it provided a means for assessing not only district-level hazards, but also the vulnerability and risks of housing stock. It was greatly utilized by State Governments and their agencies in order to develop micro-level action plans on how to reduce the impact of natural disasters since buildings and housing are commonly damaged or destroyed due to natural disasters, resulting in life losses and disruptions to socio-economic activities.

The revised Atlas 2019 reflects advances in scientific & technical knowledge, addition of new datasets, results of disasters caused by earthquakes and cyclones, possible damage from landslides, floods, thunderstorms, failures of roads and trains during disasters, changes in the political map of the country, and new statistics on walling and roofing data of houses (BMTPC, 2019). Table 3 and Fig. 4 shows different Housing typologies used in BMTPC, based on wall and roof type and material identified in India and also their Damage risk under various hazard intensities.

Table 3: Damage Risk to various Housing Category identified by BMTPC (BMTPC, 2019)

Damage Risk to Housing under various Hazard Intensities

Category (Type of Wall and Roof)	EQ Intensity MSK				Wind Velocity m/s				Flood Prone
	≥IX	VIII	VII	≤VI	55 & 50	47	44 & 39	33	
A1. Mud wall (All roofs)	VH	H	M	L	VH	H	M	L	VH
A2.a. Unburned Brick Wall (Sloping roofs)	VH	H	M	L	VH	H	M	L	VH
A2.b. Unburned Brick Wall (Flat roofs)	VH	H	M	L	VH	H	M	L	VH
A3.a. Stone Wall (Sloping roofs)	VH	H	M	L	VH	H	M	L	VH
A3.b. Stone Wall (Flat roofs)	VH	H	M	L	H	M	L	L	VH
B.a. Burned Brick Wall (Sloping roofs)	H	M	L	VL	H	M	M	L	H
B.b. Burned Brick Wall (Flat roofs)	H	M	L	VL	M	L	L	VL	H
C1.a. Concrete Wall (Sloping roofs)	M	L	VL	NIL	H	M	M	L	L
C1.b. Concrete Wall (Flat roofs)	M	L	VL	NIL	L	VL	VL	VL	L
C2. Wood Wall (All roofs)	M	L	VL	NIL	VH	H	M	L	H
C3. Ekra wall (All roofs)	M	L	VL	NIL	VH	H	M	L	H
X1 GI and other metal sheets (All roofs)	M	VL	NIL	NIL	VH	H	M	L	H
X2 Bamboo, Thatch, Grass, Leaves, etc. (All roofs)	M	VL	NIL	NIL	VH	VH	H	L	VH

Housing Category : Wall Types

Category - A : Buildings in field-stone, rural structures, unburnt brick houses, clay houses

Category - B : Ordinary brick building; buildings of the large block & prefabricated type, half-timbered structures, building in natural hewn stone

Category - C : Reinforced building, well built wooden structures

Category - X : Other materials not covered in A,B,C. These are generally light.

Notes: *1. Flood prone area includes that protected area which may have more severe damage under failure of protection works. In some other areas the local damage may be severe under heavy rains and chocked drainage.*

2. Damage Risk for wall types is indicated assuming heavy flat roof in categories A, B and C (Reinforced Concrete) building

3. Source of Housing Data : Census of Housing, GOI, 2011

Housing Category : Roof Type

Category - R1 - Light Weight (Grass, Thatch, Bamboo, Wood, Mud, Plastic, Polythene, GI Metal, Asbestos Sheets, Other Materials)

Category - R2 - Heavy Weight (Tiles, Stone/Slate)

Category - R3 - Flat Roof (Brick, Concrete)

EQ Zone V : Very High Damage Risk Zone (MSK > IX)

EQ Zone IV : High Damage Risk Zone (MSK VIII)

EQ Zone III : Moderate Damage Risk Zone (MSK VII)

EQ Zone II : Low Damage Risk Zone (MSK < VI)

Level of Risk : VH = Very High; H = High; M = Moderate; L = Low; VL = Very Low

* Total No.of Houses excluding Vacant/Locked Houses

bmtpc **Building Materials & Technology Promotion Council** **Peer Group, MoHUA, GOI**

Figure 4: Damage Risk and Housing category identified by BMTPC (BMTPC, 2019)

3.3.4 Multi Hazard Risk Assessment used Globally

3.3.4.1 FEMA 154

The FEMA handbook demonstrates how to rapidly identify, inventory, and rank buildings that are at high risk of causing death, injury, or severe damage in the event of an earthquake. Rapid Visual Screening (RVS) can be carried out with a short exterior inspection, lasting 15 to 30 minutes, by trained personnel using the data collection form in the handbook. The guide is targeted at building officials, engineers, architects, building owners, emergency managers, and citizens who are interested in the topics.

Its purpose was to provide an evaluation of the seismic safety of a large inventory of buildings quickly and inexpensively, with minimal access to the buildings, and to identify those that require more detailed examination. FEMA 154 was developed by ATC under contract to FEMA (ATC-21 Project) in 1988. As with its predecessors, the Third Edition aims to identify, inventory, and screen buildings that present a potential risk. This latest version includes major improvements, such as: updating the Data Collection Form and including an optional more detailed page, preparing additional reference guides, and including additional building types that are common, considerations such as existing retrofits, additions to existing buildings, and adjacency, and many others (FEMA, 2015).

3.3.4.2 Flood Vulnerability Assessment survey

The Flood Vulnerability Assessment survey form prepared by the Asian Institute of Technology (AIT) Bangkok and Climate Technology Centre and Network (CTCN) (Peiris, 2015) has 5 Sections: (i) General Information (ii) Type of Building (iii) Flood damage and cost (iv) Flood emergency response (v) Effect on livelihood and income and was designed for Residential, Institutional, Commercial/Industrial damages and Infrastructure damages. Refer (Singh, 2005) for detailed Survey form.

3.3.4.3 Landslide Vulnerability Assessment survey

Scientists and researchers focus more on researching landslide susceptibility and the hazard component rather than assessing the vulnerability of buildings to landslides. Even when the same construction material is used, construction practices vary across the country. Currently, there is no standard method for determining building vulnerability by using indicators.

The parts covered by Landslide risk assessment survey forms are (i) General information (ii) Building Function (iii) Vulnerability Indicators like Architectural Features, Material Characteristics, Structural Features, Geographical features, and quality of Workmanship, Construction & maintenance, etc. which are also covered during RVS and has been covered in the proposed survey form CitSci, GIS based data collection app for landslide (Singh et al., 2019).

3.4 Features required for a Multi Hazard Survey Form for IHR

3.4.1 Gaps Identified in existing survey forms

Existing Survey forms have their strengths & weaknesses. After studying various survey forms for Risk assessment prepared by various national and international authorities, it is observed that hill-specific survey forms that can take care of multiple aspects of risk and sustainability assessment together do not exist. Available forms are complicated, not-so user friendly, consisting of terminologies difficult to communicate and comprehend, no pictorial clues for understanding, involve several rounds of calculations for coherent multi-hazard risk evaluation using the data, and most importantly, they are not hill site-specific or designed for the Indian Himalayan region.

Hills have their own situation, condition, geography, climate, development trends, construction practices, culture, etc., and they are distinctly different from other regions. RVS is mostly used in India to assess the visual structural vulnerability of the building, as it involves no structural calculations. On the other hand, SVA (Simplified Vulnerability Assessment) and DVA (Detailed Vulnerability Assessment) are for the detailed structural survey of a building, and therefore more precise and use engineering information along with more explicit data on ground motion. Data filling is not easy enough for the surveyor and requires a very high level of engineering knowledge, skills, and experience. Pictorial explanation from surveyor point of view can ease the communication. Most of the survey forms are focused on single hazard, (mostly for seismic evaluation of a building) irrelevant of multi hazard from Himalayan point of view, and how prone a building's location is to other hazards. Integration between risk understanding and sustainable development is too limited or non-existent. Thus, it has been observed that there is an immense need to design hill-specific questionnaires for multi-hazards risk assessment for Indian Himalayan Region.

3.4.2 Comparative Study of some risk assessment survey forms mostly used in India

Table 4 shows the comparative analysis of Risk assessment survey forms developed by various organizations and mostly used in India with the proposed Multi-Hazard RVS. Forms have been compared on various sections like typology, General Information, History of Disasters, Site Conditions, Building geometry, structural and non-structural component of a building etc.

Table 4: Comparative Study of some risk assessment survey forms mostly used in India

		1	2	3	4	5	6	7
Developed by/for		ARYA	FEMA	NDMA	IIT-B	HPSDMA	BMTPC	MH-RVS (Proposed)
Source		Arya, 2006	FEMA, 2015	NDMA, 2020	Sinha & Goyal, 2004	Kumar et al., 2016	BMTPC, 2019	Author
Typology	A1: Mud & Unburnt Brick			□	□		□	□
	A2: Stone Wall	□		□	□	□	□	□
	B: Burnt Brick	□	□	□	□	□	□	□
	C1: Concrete Wall	□	□	□	□	□	□	□
	C2: Wood Wall		□		□		□	□
	X: Other Materials			□			□	□
	Steel	□	□		□			□

General Information	About Building and owner	☐	☐	☐	☐	☐		☐
	Sketch/Photo and drawings	☐	☐		☐			☐
	Occupancy (Day & Night)	☐	☐		☐	☐		☐
	Cost of Construction					☐		
	Construction quality and Maintenance		☐	☐	☐	☐		☐
Disaster History	Seismic Zone		☐	☐	☐		☐	☐
	Disaster History and Damage status					☐		☐
	Disaster cause					☐		
	Retrofitting history							☐
Site Condition	Location of building				☐			☐
	Site Condition			☐		☐		☐
Building Geometry	Dimension of Building					☐		
	Shape of Building, floors	☐	☐	☐	☐	☐		☐
	Re-entrant corners					☐		☐
Foundation	Type of Sub-Soil	☐	☐	☐	☐	☐		☐
	Foundation detail	☐				☐		☐
	Depth of ground water table	☐		☐		☐		☐
Walls	Walls details	☐	☐	☐		☐	☐	☐
	Separation of walls at joint			☐				☐
	Wall failure observed			☐		☐		☐
Earthquake Bands	Earthquake band details and status			☐		☐		☐
Cracks	Cracks details			☐		☐		☐
	grade of cracks	☐		☐		☐		☐
Openings	Opening(s) details			☐		☐		☐
	Frames details near opening							☐
Roof and Floor	Type and material		☐	☐		☐	☐	☐
	Roof's attachment with walls			☐		☐		☐
	Failures observed					☐		☐
Pounding effect	Height of building			☐		☐		☐
	distance from closest building							☐
	Quality of adjacent building		☐	☐		☐		☐
Heavy weight on top	Type and positioning of Heavy weights					☐		☐
	Intact status with structure							☐
Parapet	Parapet material			☐		☐		☐
	Parapet intact with structure			☐				☐
Overhang	Type of overhangs	☐	☐	☐	☐	☐		☐
	length and intact status			☐				☐
Staircase	Staircase details	☐		☐		☐		☐
	Lift status							☐
Column and Beam	Column Beam details			☐		☐		☐
	Beam with infill wall		☐					☐

	Connection and continuity	□		□				□
Basement	No. of basement					□		□
	Column and retaining Wall							□
Soft Storey	Soft Storey’s details		□	□		□		□
High Wind	Potential threat from wind							□
Landslide	Position of potential landslide	□	□	□				□
	Stabilized slope status		□	□				□
	Barriers to rockfall			□				□
Industrial	Potential threat from Industrial Hazard							□
Fire	Fire Safety Status					□		□
	Location of potential fire threats							□
Climate Change	Understanding & Concern							□
Non-Structural Elements	Cantilever availability (Chimneys, Balconies, Parapet, Sunshades, claddings)	□	□	□	□	□		□
	Other Non-Structural elements	□	□	□	□	□		□
	No. of unattached Non-structural elements							□
								□: Concern (major/minor)

4 IHR Specific MHRA Survey Form Preparation

4.1 Survey Form Preparation

The proposed survey form is a modification of the Rapid Visual Screening (RVS) survey questionnaire, i.e., a form used for structural and non-structural components of a building that performs during an Earthquake. In the original RVS questionnaire no other hazards are considered. A building's location on a vulnerable site, its structural condition, and performance can lead to disastrous situations. The other hill-specific hazards are also incorporated into the proposed form to identify the risk components from multi-hazards. Whilst the Himalayan region is prone to earthquakes as per India's Seismic Zonation Map (Fig. 3), the proposed survey form also covers other hazards like landslide, flood, industrial explosion/emissions, fire vulnerability, hydro-climatic factors, etc., which will be addressed one by one in this paper.

4.2 Preliminary Survey

Before conducting the Pilot survey, a preliminary survey has been conducted to test the proposed form, research methodology, and identifying gaps in the existing survey form.

This small assessment also evaluated the RVS form with minor enhancements to evaluate its performance and confirm gaps, and to see if it can meet the requirement for risk assessment at other areas with similar geographical characteristics and conditions as experienced in the Indian Himalayan Region.

The Preliminary survey was conducted at 5 Gram Panchayats of Chinyalisaur sub-district in Uttarkashi, Uttarakhand, namely Chinyalisaur, Dhanpur, Dharasu, Hidhara, and Bagi, in October and November 2019, using Draft MHRA Survey form. Some of the pictures of the visit are provided in ig5.

Figure 5: View of Site selected for Pilot Survey

The preliminary survey was conducted to determine (1) Whether the questions are clearly framed? (2) Does it cover all the requirements as per hill communities? (3) Is the wording of the questions correct enough to lead to the desired outcomes? (4) Are the questions as well options for answers suggested hill specific or not? (5) Are the questions positioned in the most satisfactory order? (6) Do surveyors and respondents of all classes understand the questions? (7) Are the questions and their options self-explanatory or not? (8) Do the sections in the survey form cover risk assessment related questions for all identified hazards or not? (9) Are the questions as per construction practices and construction materials available on hills or not? (10) Is there any need to add some questions or specific, or do some need to be eliminated so as to improve the flow of the survey session. (11) Do the surveyor and respondent understand the importance of this survey or the objective behind this survey and responded in that way?

4.2.1 Observations during Preliminary survey

Feedback from the Preliminary study proved very helpful in determining the key gaps and shortcomings of the form design and in informing improvements to the proposed form design. Specifically (1) The preliminary study showed that a surveyor's observations of a project site, his or her understanding of each question, and his/her strategy for convincing the residents to provide accurate data played a significant role in risk assessment. (2) In some questions, the use of technical terms or difficult words, or questions designed to gather too much data at once, discourage respondent interest in responding further and make the Surveyor uncomfortable to proceed. (3) The questionnaire may not be self-explanatory and requires someone with civil engineering training to fill it out. (4) Building geometry, construction practices, construction materials, and development trends play an essential role during any hazard, thus existing building related questions and options must be incorporated. (5) Survey questions are developed primarily from observations made by survey and engineers as opposed to responses from residents. (6) If the Surveyor is not familiar with the terminologies and aims behind filling out the questionnaire, it leads to no response or respondents sometimes loose interest to answer further. (7) An unclear survey vision, study purpose, and inadequate training of the Surveyor will make it difficult to explain the importance of data collection to the respondent, leading to unclear questions and less accurate responses. (8) Surveyors should be trained enough to pick out the correct option from respondents' lengthy responses. (9) Need of pictorial representation of answers/options for better understanding of the Surveyor. (10) Different answers are obtained when questions are arranged inappropriately or answers are arranged incorrectly. (11) Observing the interaction between multiple hazard types in the same area is a challenging aspect of natural hazards risk assessment.

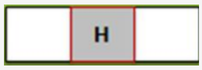
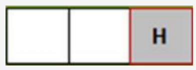
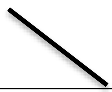
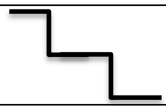
4.3 Proposed MHRA Form

After the Preliminary survey conducted at the Chinyalisaur sub-district, significant points were identified/observed that has been incorporated in the Proposed survey form of Multi-Hazard at hill locations with all the simple content and graphical inputs for better understanding. Hence, the modifications from a Multi-hazard risk point of view and surveyors' point of view can be seen in the proposed form (Table 5 and 6).

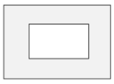
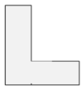
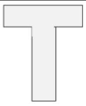
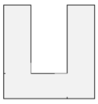
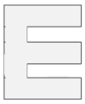
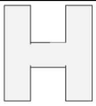
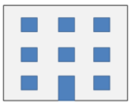
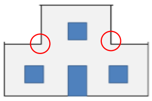
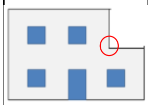
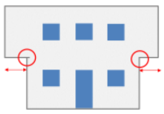
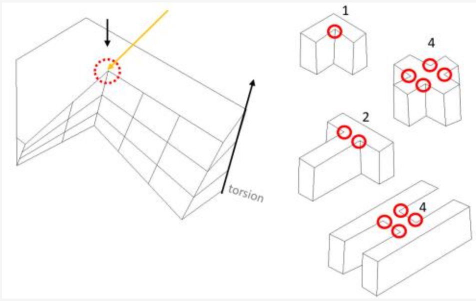
These amendments and the full survey form are presented below.

Table 5a: Proposed MHRA Survey form (Part A)

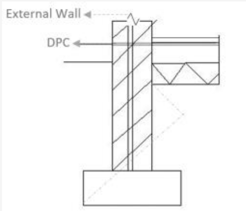
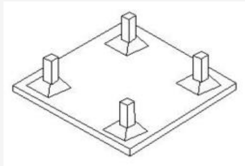
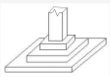
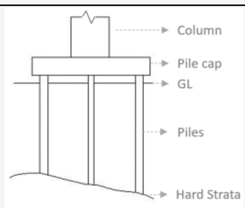
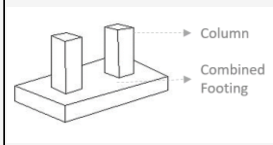
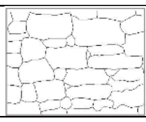
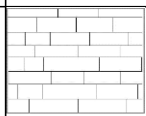
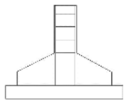
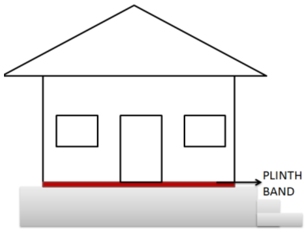
Rapid Visual Screening (RVS) form						
SURVEYOR						
1	Name of the Surveyor					
2	Mobile no. of Surveyor					
3	Inspection Data					
4	Inspection Time					
GENERAL INFORMATION						
5	Name of Building/Owner					
6	Address					
7	Town/City, District and State					
8	Coordinatnates					
9	Total No. of Building Blocks present inpremises					
10	Name of Block to be survey					
11	Draw Sketch of Site Plan					
12	Function of Block	Residential (Individual House)		Residential (Appartments)		Residential (Other)
		Educational (School)	Educational (College)	Educational (Institute/ University)		
		Lifeline (Hospital)	Lifeline (Police Station)	Lifeline (Fire Station)	Lifeline (Power Station)	Lifeline (Water/ Sewage Plant)
		Commercial (Hotel)	Commencial (Shopping)	Commercial (Recreational)		Commercial (Other)
		Office (Govt.)		Office (Private)		
		Mixed Use (Residential and Commercial)		Mixed Use (Residential and Induustrial)		Mixed Use (Other)
		Industrial (Agriculture)		Industrial (Live Stick)		Industrial (Other)
13	Occupancy in day time	0 to 10	11 to 50	51 to 100	101 to 1000	more than 1000
14	Occupancy in night time	0 to 10	10 to 20	51 to 100	101 to 1000	more than 1000
15	Name of Owner					
16	Name of Contact Person					
17	Contact No. of Contact Person					
18	Year of Construction:					
19	Structural or Construction drawings available?	Yes		No		

20	Total built up area (sq.m)					
21	No. of Floors	Low Rise (1 to 3)	Mid Rise (4 to 7)		High Rise (7 and above)	
22	What is the overall Construction quality	Excellent	Good	Average	Poor	Very Poor
23	What is the overall Maintainance Status	Excellent	Good	Average	Poor	Very Poor
	DISASTER HISTORY					
24	Seismic Zone	Zone V	Zone IV	Zone III	Zone II	Don't know
25	Did this area faced any Major disaster?:	Yes		No		
26	If Yes in Q.25, Which Disaster?:	Earthquake	Flood	Landslide	Wind	Industrial
		Fire	Other	If Other, Specify		
27	If Yes in Q.25, in which date/year					
28	If Yes in Q.25,What is the major damage status	No effect	Minimum Effect	Medium Effect	Maximum Effect	
29	Is the building Retrofitted/ Renovated ever?	Yes		No		
30	If Yes in Q.29, Year of last renovated?					
	SITE CONDITION					
31	Location of Building:	Isolated	Internal Corner		End	
						
32	Slope of Ground:	Flat Terrain	Gentle Slope	Steep Slope	Terraced land	
						
33	Cut & Fill Material:	RCC	Hybrid		Other	
34	Is there Visible cracks on the ground	Yes, Many		Yes, few		No
35	Is there any open space in the property?	Yes, more than 1500 sq.ft		Yes, less than 1500 sq.ft		No
36	What is the total area of Open spaces in the campus (in sq.ft) :					

Note: RCC: Reinforced Cement Concrete; H: House position

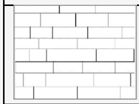
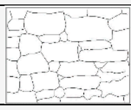
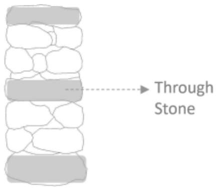
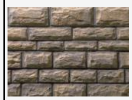
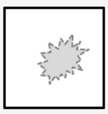
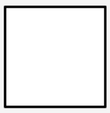
	BUILDING GEOMETRY					
37	Shape of Building Block in Plan:	Square	Rectangle (L<=3B)	Narrow Rectangle (L>3B)	Rectangle with courtyard	L-Shaped
						
		T-Shaped	U-Shaped	E-Shaped with Central courtyard	H-Shaped	Other
						
38	Shape of building Block in Elevation: No. of Reentrants corner in Plan	Not stepped	Stepped near centre	Stepped near the end	Heavy upper floor	
						
39	No. of Reentrants corner in Plan					
40	Is extra strength available in reentrants corner?	Yes		No		
41	No. of Floors	only G	G+1	G+2	G+3	> G+4

Note: G: Ground floor

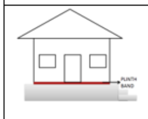
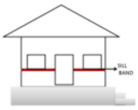
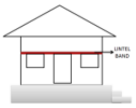
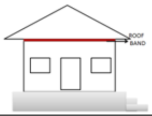
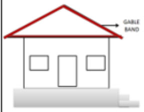
FOUNDATION						
42	Type of Sub Soil:	Rock	Gravel or Sand		Soft or Medium	Other
						
43	Type of Foundation:	Strip		Raft		Isolated
						
		Pile		Combined		Other
						
44	Basic Construction material of Foundation:	Adope	Stone	Brick	RCC	Other
						
45	Mortar Material in Foundation:	Dry Masonry	Mud	Lime	Cement	Other
46	Plinth beam available?	Yes	No			
47	Sinking in Foundation?	Yes		Partial	No	
48	If Yes or Partial in Q.47, What is the Reason for Sinking?	Cause of nearest water resources		Without any water resources		Other (specify)
49	Depth of ground water table					Don't know

506

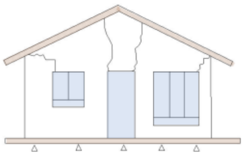
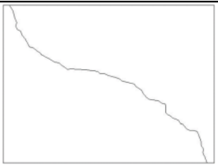
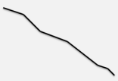
507

WALL						
50	Type of Wall:	Brick	Stone	Confined	RCC	Other
				Only Column available & No Beams	Column & Beam, both available	
51	Is through-stone used in Stone Wall?	Yes	Partial	No		
52	What is the Wall material?	Adobe or Mud Wall	River Boulder wall	Quarry Stone wall	Dressed wall	fired brick wall
						
		hollow concrete block wall			Other	
						
53	Type of mortar	Dry masonry	Mud	Lime	Cement	Other
54	Thickness of interior Wall (in mm):	< 115 mm	115 mm (4.5")	230 mm (9")	230 to 450 mm	> 450 mm
	Length of longest interior wall (in meter)					
	Max. Height of the wall (in meters)					
55	Thickness of exterior Wall (in mm):	< 115 mm	115 mm	230 mm	230 to 450 mm	> 450 mm
	Length of longest exterior wall (in meter)					
56	Thickness of Mortar (in mm):					
57	How many Separation of walls at T and L junction?					
58	Wall Failure type observed:	Bulging of wall	delaminating of wall	tilting of walls	dampness in wall	No failure
						
	No. of walls with these failures					

Note: RCC: Reinforced Cement Concrete

EARTHQUAKE BANDS						
59	Which of the Earthquake bands available?	Plinth Band	Sill Band	Lintel Band	Roof Band	
						
		Gable Band	Door Band	Window Band	Corner Band	No Band
						
60	If Bands available in Q.59, What is theMaterial of Band:	Wood	Reinforced brick	Reinforced concrete	Other (Specify)	
61	If Bands available in Q.59, Thickness of Band (in mm):					
62	If bands available in Q59, Are the bands continuous?	Yes	Partial	No		Don't know

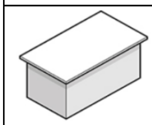
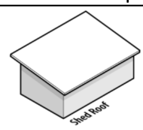
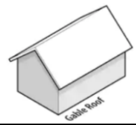
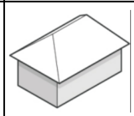
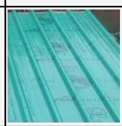
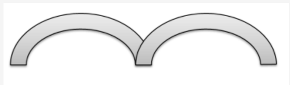
512

CRACKS						
63	Type of Cracks:	Structural cracks		Superficial cracks		N/A
	Note: Superfial cracks are seen in one side of wall, on the other hand structural cracks can be seen on both side of the wall					
64	Type of Structural cracks:	Diagonal cracks	Vertical cracks	Horizontal Cracks	Remark	
						
	Specify, No. of Cracks in each case					
	Specify, Length of cracks in each case (in cm)					
	Grade of Cracks	Grade 5	Grade 4	Grade 3	Grade 2	Grade 1
65	Are there any cracks on	Column	Beam	Near Openings	Near corner	No cracks

513

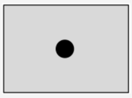
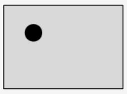
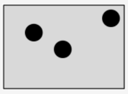
	OPENING				
66	Is there any opening(s) larger than 50% of the length of the wall	Yes, all		Yes, few	No
67	Are there any opening close to wall junction or corner or to floor/roof	Yes, all		Yes, few	No
68	Is frames available around the door?:	Yes		Partial	No
69	If Yes/Partial in Q.68, What is the material of Frame used:	Wooden	MS/SS	other (Specify)	
70	Is frames available around the window	Yes		Partial	No
71	If Yes/Partial in Q.70, What is the material of Frame used:	Wooden	MS/SS	other (Specify)	
72	Is Grills available around the window?:	Yes		Partial	No

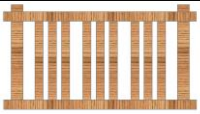
Note: MS: Mild Steel, SS: Stainless Steel

	ROOF AND FLOOR					
73	Type of Roof:	Flat Roof	One side slope	two side slope	four side slope	Other (specify)
						
74	Material of Roof:	RCC		Reinforced brick slab	Tile or slate	CGI Sheets
						
		Jack arch roof		Wooden	Other (Specify)	
						
75	Are the roof anchored into the wall	Yes		Partial	No	
76	Type of Roof failures observed	Sagging	Cracks	Dampness	Other	No failure
77	Type of Flooring	Mud	Stone	Concrete	Wood.bamboo	Mosaic floor tile

Note: RCC: Reinforced Cement Concrete; CGI: Corrugated Galvanized Iron

	POUNDING EFFECT DETAILS					
78	Height of Structure /Block (in meters)					
79	Is there any adjacent building, which is very close (no gaps) to this building	Yes	with very little gap			No
80	Distance from nearest buildings (in meters)					
81	Quality of adjacent building	Very Good	Good	Moderate	Poor	Very Poor

	HEAVY WEIGHT ON TOP					
82	Type of Heavy weight present on the top of the building?	water tank (Concrete)	Water tank (Plastic)	Car Parking on the top of the building		Big hoarding
		Heavy generator/ machine	Communication tower	Roof top Garden	Other	None
83	If Yes in Q.82, What is the Position of Heavy weight?	Centric	Eccentric	Distributed	Corners	Remark
						
84	Are the heavy weight intact properly with structure?	Yes		Partial	No	

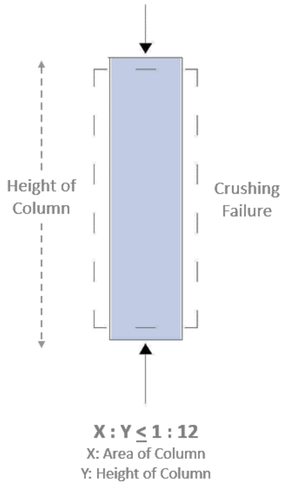
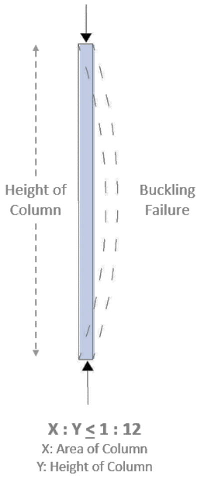
	PARAPET WALL				
85	Is Parapet wall present at roof	Yes	Partial	No	
86	If Yes or Partial in Q.85, What is the Material of Parapet Wall?	Lightweight (Wooden, MS/SS)	Heavy weight (RCC, Brick)		Remark
					
87	Intact with structure	Yes	Partial	No	

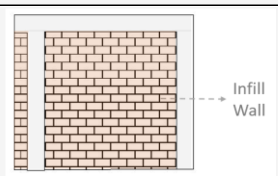
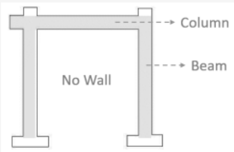
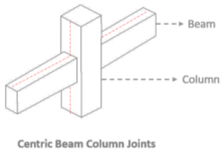
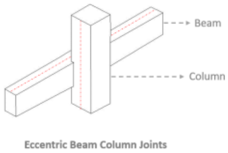
Note: MS: Mild Steel, SS: Stainless Steel, RCC: Reinforced Cement Concrete

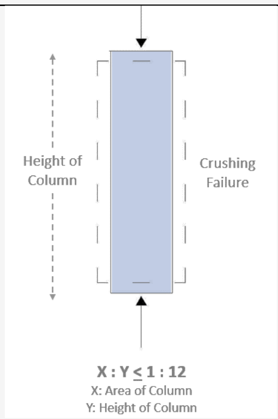
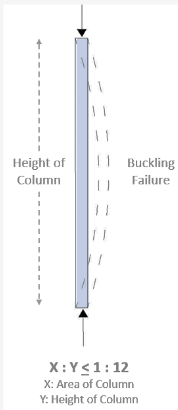
	OVERHANGS		
88	Overhangs present	Yes	No
89	Length of overhangs (meters)		
90	Overhangs with structural	Yes	No
91	Overhangs with Brackets /beam	Yes	No

	STAIRCASE					
92	Staircase present	Yes			No	
93	Staircase placed at symmetrical location in plan of the bulding	Symmetrical			Un-symmetrical	
94	If Yes in Q.92, What is the Material of Staircase?	RCC	Brick	Wooden	MS/SS	Other
95	If Yes in Q.68, Is Staircase intact with building structure?	Yes			No	
96	Lift Status?	Intact	Not Intact		Not Available	

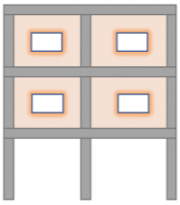
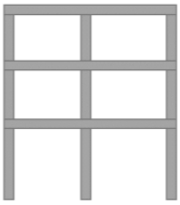
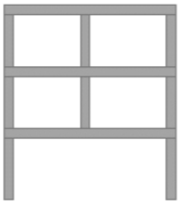
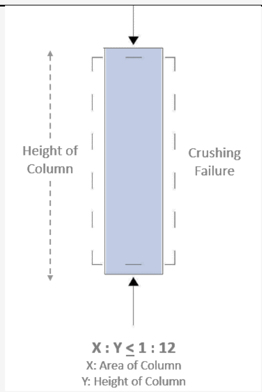
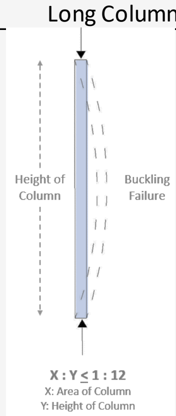
Note: MS: Mild Steel, SS: Stainless Steel, RCC: Reinforced Cement Concrete

COLUMN						
97	Column available?	Yes			No	
98	If yes in Q.97, What is the type of Column?	Short Column 			Long Column 	
99	Material of Column	Concrete	Masonry (Brick/ Stone)	Wood	Steel	Other

BEAM						
100	Beam available?	Yes			No	
101	If Yes in Q.100., Beam with infill walls available?	Yes 		Partial	No 	
102	If Yes in Q.100., Beam – Column connections?	Centric 		Eccentric 		Other
103	Beam -Beam Connection?	Centric		Eccentric		Other
104	If Yes in Q.100., Material of Beam	Concrete	Masonry (Brick/ Stone)	Wood	Steel	Other

BASEMENT					
105	Is Basement Available?	Yes			No
106	If Yes in Q.105, No. of Basement				
107	Effective height of column in basement?	Short Column			Long Column
					
108	Retaining wall available ?	Yes			No
109	If Yes in Q.108, What is the Material of the retaining wall ?	RCC	Brick	Stone	Other

Note: RCC: Reinforced Cement Concrete

SOFT STOREY				
	A soft story building is a multi-story building in which one or more floors have windows, wide doors, large unobstructed commercial spaces, or other openings in places where a shear wall would normally be required for stability as a matter of earthquake engineering design.	 Stiff and Strong upper floors due to masonry infills	 The columns in one storey longer than those above	 Soft storey caused by discontinuous column
110	Soft Storey available ?	Yes		No
111	Effective height of column in basement?	Short Column		Long Column
				

112	Is shearwall available in Soft Storey?	Yes		Partialy	No
113	Retaining wall available ?	Yes			No
114	If Yes in Q.113, What is the Material of the retaining wall ?	RCC	Brick	Stone	Other

Table 6a: Proposed MHRA Survey form (Part B)

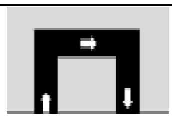
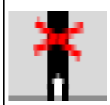
MULTI HAZARD SURVEY FORM						
FLOOD						
1	Is the site low lying or prone to water logging?	Yes			No	
2	Is there any water body near the site?	Yes			No	
3	What is the type of water body and whether it is prone to flooding?	Lake, flood prone	Lake, not flood prone	River, flood prone	River, not flood prone	N/A
4	What is the distance from the nearest water body?	0 - 250 M	250 - 500 M	500 - 1000 M	1 KM - 2 KM	2 KM and above
5	What is the potential damage level due to the expected duration of flooding?	Very High	High	Medium	Low	Very Low
6	Is the plinth made up of non-erodible material?	Yes			No	
7	What is the height of the plinth? (in meters)					
HIGH WIND						
8	What is the average wind speed in this location	Maximum Speed		Minimum Speed		
9	Are there trees and/or towers too close to the building that may fall on it during high wind/cyclone?	can stop building from functioning		threat can damage building but not hamper functioning		No threat
10	Do the door and windows have a good and accessible latch?	if neither doors or windows have accessible and good latches.		If some of the doors and windows have accessible and good latches		If both doors and windows have accessible and good latches
11	Is there a covered walkway for building to building connection?	no covered walkway		weak covered walkway		strong covered walkway

	LANDSLIDE					
12	Is there any hills near to the building, which can cause damage due to landslide	Yes			No	
13	If Yes in Q.12, what is the distance of the base off the Hill from building?	Less Than 30 M	30 M - 100 M	100 - 250 M	250 - 500 M	More than 500 M
14	Is the slope near the building stabilized?	Yes			No	
15	Are there any large rocks or potential falling hazards near the building?	Yes			No	
16	Are there barriers to rockfall ?	Yes			No	

534

	INDUSTRY					
17	Is there any industry near to the building, which can cause damage due to industrial hazard, fire etc.	Yes			No	
18	If Yes in Q.17, how many active industries are there?	Yes			No	
19	What is the distance of nearest Industry from building?	0 - 100 M	100 - 250 M	250 - 500 M	500 - 1000 M	More than 1 km
20	What is the distance of nearest Petrol Pump from building?	0 - 100 M	100 - 250 M	250 - 500 M	500 - 1000 M	More than 1 km

535

	FIRE					
21	Are the access roads from main street wide enough to allow one fire engine to reach, reverse and return to the main road?	two or more such access roads		one such access road		No access road
						
22	Are there potential fire threats within 30 meters of the building such as petrol pump, electrical substation, combustible materials store, etc.?	Yes			No	
23	Is there adequate open assembly area for people during any emergency?	enough space	inadequate open space (1-4 square feet per student)		negligible	
24	Is main meter box and switch box located in the staircase/ entrance lobby/ passage/ corridor?	Yes			No	

536

<table>
<tr><td rowspan="2">25</td><td rowspan="2">Are the main meter box and switch box enclosed in a metallic box?</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">26</td><td rowspan="2">Is there more than 1 staircase which can be used as a fire escape staircase ideally at maximum distance from the other staircase?</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td rowspan="3">27</td><td rowspan="3">In case of Public building or Life line building, Are there proper signages in the campus for Emergency Exit, Fire equipment etc.?</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3">
</td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">28</td><td rowspan="2">Is the kitchen located at a safe distance from escape route,gathering point, staircase, passage corridor?</td><td>Yes, beyond 50 m</td><td>Yes, within 20-50 m</td><td>Yes, within 10-20 m</td><td>adjacent</td><td>Kitchen Not Available</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">29</td><td rowspan="2">Is the ceiling material safe from fire?</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">31</td><td rowspan="2">Is the transformer too close to the compound wall or inside the building?</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">32</td><td rowspan="2">Are there overhead cables running through or near premises/building?</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">33</td><td rowspan="2">If there is a forest area near the building?</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>34</td><td>What is the distance of the tree line from the building?</td><td colspan="5"></td></tr>
<tr><td rowspan="2">35</td><td rowspan="2">Is there any combustible construction material present in the building?</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
</table>

CLIMATE CHANGE						
36	How much do you think climate change threatens your personal	Very Likely	Likely	Neutral	Unlikely	Very Unlikely
37	Which issues are of more concern in your opinion? (On the scale of 10, more marks to most concerned)	Climate change/Global Warming	Poverty	Over-population	Un-employment	Crime
		Infectious Diseases	Economic Situation	Unplanned Infrastructure	Deforestation	Air pollution
		Water pollution	Tourism growth	Poor Waste Management	Extinction of species	Traffic
38	In your opinion, What is the reason that the temperature on earth has been rising over the past decade?	Human Activities	Natural Causes	No Change	Don't know	Other
39	How much do you think the following has contributed to global climate change? (on scale of 10, more marks to most contributer)	Deforestation	Overpopulation	Tourist growth	Landuse Landcover	Greenhouse gases
		Industrilization	Melting of Ice	Warming of water surface	Other	Don't know

Non Structural Risk/ Falling Hazard							
40	List of Nonstructural elements which are vulnerable to falling or not attached properly	*Element*	*Need Attentio*	*Number*	*Element*	*Need Attentio*	*Number*
		Fan			Wooden Frame at Roof		
		Tubelight			Door		
		Electrical Wires			Window Frames		
		AC			Heavy Machinaries		
		Open Shelve (Glass)			Cylinder in Open space		
		Open Shelve (Iron)			Board		
		Wardrobe (Wooden)			Ventilator		
		Wardrobe (Iron)			Fire Extinguisher		
		HeavyTable			Cantilever Chimneys		
		Heavy Frames			Cantilever Balconies		
		Heavy Furnitures			Cantilever Sunshades		
		Heavy weight on top of almirah			Other		
41	No. of Exits in the Room:						
42	What is the status of Electrical Safety in the Room	GOOD		OK		POOR	

4.4 Risk Score Computation

After all the parametric studies from various Indian Standard codes and Reports ((NDMA, 2020), (URDPFI, 2015); IS-13828 (1993); IS-4326 (1993); IS-1893-1 (2016); IS-13935, 2009; IS-15988 (2013)) on ideal building parameters and weak components of a building from the design, construction, site condition, surrounding condition, location and hazard points of view, risk scores were decided on an average basis on 24 components separately (refer section 4.5 of this paper) for better judgment and understanding. Risk scores were derived from the proposed survey form by appropriately weighing the data points against a risk number chart with higher weightage given to higher risk (Chouhan et al., 2022b). The data was then aggregated on a scale of ten (Table 7). For example, if a building answers all weighted MCQs with the highest risk option, it will be scored 10/10 and similarly for low risk and moderate risk. All questions in the questionnaire were not weighted; those with ambiguous risk consequences were left un-weighted to be studied objectively. The risk scores intend to give a relative idea of where the risk lies within a building and among buildings to enable prioritization during risk mitigation planning.

Table 7: Risk Score Computation, Source adapted from (Chouhan et al., 2022b)

Risk Score	0 to 2	2.1 to 4	4.1 to 6	6.1 to 8	8.1 to 10
Color Code					
Risk Status	Very low	Low	Moderate	High	Very high
Building Status	Very Safe	Safe	Moderately safe	Unsafe	Very Unsafe
Recommendation	Need Maintenance	Need Attention and Maintenance	Need Attention and SVA	Required DVA and Retrofitting	Required Retrofitting urgently

4.5 Pilot Survey

After finalization of the proposed MHRA Survey form, a Pilot survey was conducted at 10 schools of Uttarakhand state. The results of the building level survey and campus level survey are shown below in section 4.5.1. and 4.5.2.

4.5.1 Result of Rapid Visual Screening Survey

As per IS Code 13935 (2009), the key goal of seismic reinforcement is to improve a weakened building's seismic resilience as it is being repaired, making it stronger in the event of potential earthquakes. The individual results of 17 components of RVS are elaborated, which highlights the weaker part that needs attention in a building.

Table 8: *Result of RVS of 10 schools through Proposed form*

SN	**Risk Status**	**Very Low Risk**	**Low Risk**	**Moderate Risk**	**High Risk**	**Very High Risk**	**Total**

1	Site Condition	54 %	13 %	29 %	2 %	2 %	100 %
		32	8	17	1	1	59 blocks
2	Building Geometry	34 %	27 %	14 %	20 %	5 %	100 %
		20	16	8	12	3	59 blocks
3	Foundation	27 %	22 %	51 %	0 %	0 %	100 %
		16	13	30	0	0	59 blocks
4	Wall	36 %	37 %	27 %	0 %	0 %	100 %
		21	22	16	0	0	59 blocks
5	Earthquake Bands	0 %	0 %	7 %	10 %	83 %	100 %
		0	0	4	6	49	59 blocks
6	Cracks	2 %	83 %	0 %	0 %	15 %	100 %
		1	49	0	0	9	59 blocks
7	Openings	63 %	17 %	19 %	1 %	0 %	100 %
		37	10	11	1	0	59 blocks
8	Roof	7 %	3 %	10 %	78 %	2 %	100 %
		4	2	6	46	1	59 blocks
9	Pounding Effect	25 %	0 %	5 %	39 %	31 %	100 %
		15	0	3	23	18	59 blocks
10	Heavy Weight on top	95 %	0 %	2 %	0 %	3 %	100 %
		56	0	1	0	2	59 blocks
11	Parapet	93 %	0 %	7 %	0 %	0 %	100 %
		45	0	4	0	0	59 blocks
12	Overhang	53 %	0 %	15 %	0 %	32 %	100 %
		31	0	9	0	19	59 blocks
13	Staircase	80 %	0 %	3 %	12 %	5 %	100 %
		47	0	2	7	3	59 blocks
14	Column	51 %	0 %	12 %	0 %	37 %	100 %
		30	0	7	0	22	59 blocks
15	Beam	32 %	2 %	7 %	7 %	52 %	100 %
		19	1	4	4	31	59 blocks
16	Basement	100 %	0 %	0 %	0 %	0 %	100 %
		59	0	0	0	0	59 blocks
17	Soft Storey	100 %	0 %	0 %	0 %	0 %	100 %
		59	0	0	0	0	59 blocks

4.5.2 Result of Multi-Hazard Survey

The survey was conducted by considering the campus of the school as one unit. It primarily focuses on the location of school premises under a vulnerable zone or not, if yes, to which kind of hazard. It solves the question of how the school campus is prepared. The result of multi-hazard survey is shown in the Fig. 6 below:

Flood Risk Assessment				Total
10%	50%	30%	10%	100%
1 s	5 schools	3 schools	1 s	10 Schools

Wind Risk Assessment			Total
70%	20%	10%	100%
7 schools	2 schools	1 s	10 Schools

Landslide Risk Assessment	Total
100%	100%
10 schools	10 Schools

Industrial Risk Assessment	Total
100%	100%
10 schools	10 Schools

Fire Risk Assessment			Total
20%	60%	20%	100%
2 schools	6 schools	2 schools	10 Schools

Non-Structural Risk Assessment		Total
80%	20%	100%
8 schools	2 schools	10 Schools

Figure 6: Graphical presentation of the results of Multi-hazards risk

The photos of the 10 schools where pilot survey was conducted is shown in the Fig. 7 below:

Figure 7: Photo of the 10 schools

5 Discussion:

5.1 Pilot Survey

The IHR requires effective and standardised Multi-Hazard Risk Assessment, and for that purpose a customized designed Survey Form has been designed to capture the unique characteristics of hill communities and assets. The proposed form performed reasonably well. Effectiveness & data collection is comfortable from both ends i.e., Respondents & Surveyor. The questions are properly framed in various sections, the language is simple and it is easy to interpret. The pictorial explanation makes it easy for surveyors to correct input data, as its explanation is self-explanatory. The objective behind the data collection is well clear to the Respondents and Surveyor.

5.2 Key features of the proposed MHRA survey form

The key features of the proposed form are it is specially designed for data collection in the Indian Himalayan region with risk of earthquake, flood, high wind, industrial hazard, non-structural risk, fire vulnerability and climate change awareness. As the value addition, the proposed survey form consist of questions related to climate change also, as the promotion of self-mobilisation and action is enhanced by awareness; it increases enthusiasm and support. It is therefore crucial to raise awareness about climate change adaptation in order to manage the impacts of climate change, increase adaptive capacity, and reduce overall vulnerability.

The proposed survey form is very useful for any type of study related to Hazard Risk assessment in hills. Time taken to complete the questionnaire, i.e. the length of the questionnaire is good enough i.e. 10 minutes for the trained civil engineer and 17 minutes for the trained non-engineering background surveyor. With practice, the surveyor can reduce time. The language of the form is simple and specific, i.e. one answer on one dimension is required, it considers all possible contingencies when determining a response and it is designed in a way that it collects more & more accurate information in less time. Questionnaires permit the collection and analysis of quantitative data in a standardized manner, ensuring their internal consistency and coherence. The question sequence is clear and smooth moving. By sequencing questions properly, the chances of misinterpreting individual questions are greatly reduced. The pictorial options make it comfortable for the surveyor to fill the answer by looking at the building.

The survey form is divided into sections so that only one thought can be conveyed at a time. It includes the advanced version of RVS that covers risk status for foundation, wall, roof, openings, beam, column, site conditions, etc. of a building. It is covering all the points required for building analysis in RVS. It covers questions related to all identified hazards that are directly indirectly contributing to risk factors. It covers all the required questions as per hill condition, situation, climate, geography, construction practices, construction materials, etc. The format, including the font and layout, is good enough to read by the surveyor. Before going into the field, the surveyor must require a reading of the full survey form carefully with all terminologies clear. It includes non-structural risk survey questions. The safety of occupants in a building following an incident can be at risk due to reduced capacity of structural components or damage to non-structural components. This hill-specific MHRA questionnaire survey may act as a risk sensitization tool.

5.3 Result of Pilot Survey

It can be seen that the detailed multi-hazard risk assessment will help the schools to identify the potential threats presented in the building as well as premises and the steps to retrofit the structure.

Due to the region's strong earthquake zonation, RVS and NSRA (Non-Structural Risk Assessment) data suggest high structural and non-structural vulnerability in almost all the 10 schools (figure 7), which assumes greater significance. On the other hand, schools need to improve their fire safety measurement and trainings. High wind and floods pose a prominent moderate to high risk. Industry and landslides, on the other hand, pose no risk. The risk of fire arises from a shortage of fire safety equipment and structural issues such as the absence of an alternate staircase, the incorrect placement of fire-risk properties, etc. Fire disasters have the potential to be catastrophic, but this should be a top priority as we advance. The wind is a significant concern in this region because it is vulnerable to frequent windstorms. High-speed winds pose a risk in the form of hazard trees/ towers, flying objects weakly latched doors/windows.

Heavy furniture (tables, cabinets) and hanging electrical items/wire products face a considerable risk of falling in the case of a tragedy in different rooms and labs. Falling hazards can obstruct escape routes and injure people as they collide with them during minor seismic shaking/earthquakes. When a disaster strikes, it's crucial for students and workers to have as little disruption as possible during the critical reaction time. Mitigation measures primarily involve simple fixes of non-structural elements with the structural element (wall and floor) and are hence, for the most part, low-cost solutions.

Overall, the total risk is rated moderate on the risk scale considered by the authors after structural and non-structural factors.

6 Conclusion

The Indian Himalayan region is facing disaster every year with significant loss of life and property, as it is very prone to multi-hazards. Thousands of studies, research, and projects are funded nationally and internationally to minimize the loss and prepare the community to face the upcoming disaster.

A questionnaire is the backbone for any survey, which is the base for all types of research work for better accuracy. This article describes why there is a need for a hill-specific survey form that focuses on the multi-hazards in hills and hill’s existing scenarios. It then described the steps of how a Hill-specific Multi-Hazard Risk Assessment Survey form was developed, validated through pilot survey, and tailored specifically for hill communities.

This article identifies gaps in the existing survey form used in India for risk assessment and highlights the problem faced by the surveyors on ground while filling these survey forms. The proposed form is a self-explanatory, pictorial, simple, easy to understand, covers hill specific important components and it addresses several hazards such as earthquakes, floods, high wind, landslides, industrial hazard, fire vulnerability and non-structural risk in the building.

The proposed survey form designed and applied under this study will help all the stakeholders to collect better information from the field and made it easy for the surveyors to understand even for non-technical person. This form will also identify the weak components of a building, construction practices, their development trend, and vulnerability of the location, so that future construction can be planned, considering the risk factors and vulnerable zones. Most of the assessment criteria for multi-hazard risks are met by the proposed survey form. The more accurate the data, the better will be its results.

The preliminary survey conducted at Chinyalisaur district of Uttarakhand validates the questionnaire and survey form, and provided invaluable feedback now incorporated in to the final survey form design. Through preliminary and pilot surveys it has been observed that the proposed form is designed in a way that it can collect more accurate information in less time. Questionnaires permit the collection and analysis of quantitative data in a standardized manner, ensuring their internal consistency and coherence. The language and sequence of questions is designed for clear and easy communication. Pictorial explanations of questions, the unique feature, provides easy flow of information between the respondents and surveyors. Thus, this hill-specific MHRA questionnaire survey may act as a risk sensitization tool.

The survey form is divided into various sections that covers firstly building specific questions as buildings play crucial roles during any hazard, and secondly location specific questions that cover the vulnerability of buildings towards other hazards. The result of the pilot survey highlights the risk status for various components of a building which will help further in utilizing the retrofitting and renovation budget in fruitful and planned way. On the other hand, the result of the pilot survey also shows location wise vulnerability i.e., vulnerability of the building towards other hazards that can help further in decision making related to disaster reduction, preparedness and planning strategies at that location for that particular identified hazard. It will also help to understand the development trend in that particular location and take action for future development strategies.

The suggested form is a proposed version of Rapid Visual Screening (RVS), which can assess the risk of any structure and includes all structural and non-structural components that respond during a seismic event. It also includes information about the building's sensitivity to possible danger zones such as landslides, floods, wind, and industrial hazards.

This study has the scope of application in other Asian countries with Himalayas like Nepal, Bhutan, China and Pakistan. Its international application will enhance the survey form and scope for future research. The proposed survey form will not only act as self-sensitization for the building owners at micro level but will also have good scope at regional level i.e., macro level, when results of all the buildings will be on single screen. The data collected using this form can be used in any study related to Multi-Hazard Risk Assessment. It can be used by civil engineers as well as non-civil engineering background people. People can self-assess their building. To do this effectively, it is crucial to reinforce the networks of science, technology, and decision-makers and create a sustainable technological outcome for disaster risk reduction.

Acknowledgment

This research was supported by National Mission for Himalayan Studies (NMHS), Project Grant No. NMH_1334_DMC and CoPREPARE, Project Grant no. IGP2020-24/COPREPARE – funded by UGC. We are indebted to the local residents who actively participated in the household survey. The authors are grateful to Mr. Tom Burkitt, from DHI, for supporting editorial and proofreading.

Data availability Statement

This article is part of doctoral research and the data collection has been done by the first author physically on-site. The data is available from the authors on the request basis.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Allen, S. K., Rastner, P., Arora, M., Huggel, C., and Stoffel, M.: Lake outburst and debris flow disaster at Kedarnath, June 2013: hydrometeorological triggering and topographic predisposition, Landslides, 13(6), 1479–1491. doi:10.1007/s10346-015-0584-3, 2015.

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

Arya, A. S.: Rapid Visual Screening of RCC Buildings, Prepared Under GOI – UNDP Disaster Risk Management Programme, Ministry of Home Affairs, India, pp 14 pp., 2006a

Arya, A. S.,: Rapid Visual Svreening of Masonry Buildings, *GOI – UNDP Disaster Risk Management Programme*, 13935, 17–41 pp., 2006b

BMTPC.: Vulnerability Atlas of India: 3rd edition, Ministry of Housing and Urban Affairs, Government of India, India, 478 pp., https://vai.bmtpc.org/, 2019

Buck, Kyle. D., and Summers, J. Kelvin.: Application of a multi-hazard risk assessment for local planning local planning, Geomatics, Nat. Hazards Risk., 11(1), 2058-2078, https://doi.org/10.1080/19475705.2020.1828190, 2020.

Chandel, V. B. S., and Brar, K. K.: Seismicity and vulnerability in Himalayas : the case of Himachal Pradesh, India, Geomatics, Nat. Hazards Risk., 1(1), 69-84, doi: 10.1080/19475701003643441, 2010.

Chouhan, S., Narang, A., and Mukherjee, M.: Multi-Hazard Risk Assessment of Schools in Lower Himalayas: Haridwar District, Uttarakhand, India, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-4333, https://doi.org/10.5194/egusphere-egu22-4333, 2022a.

Chouhan, S., Narang, A., and Mukherjee, M.: Multihazard risk assessment of educational institutes of Dehradun, Uttarakhand, Int. J. Disaster Resil. Built Environ., ISSN: 1759-5908, https://doi.org/10.1108/IJDRBE-08-2021-0091, 2022b.

COI-Census of India: https://censusindia.gov.in/census.website/, last access: 16 July 2022., 2011

Disasters in Himalayan Region: https://library.oapen.org/handle/20.500.12657/22932, last access: 16 July 2022., 2007.

Dunbar, P.K., Bilham, R.G., and Laituri, M.J.: Earthquake Loss Estimation for India Based on Macroeconomic Indicators, Risk Science and Sustainability, Edited by: Beer, T., Ismail-Zadeh, A., NATO Science (Vol 112), Springer, Dordrecht, 163-180, https://doi.org/10.1007/978-94-010-0167-0_13, 2003.

FEMA.: Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook: 3rd edition, Federal Emergency Management Agency, Washington, 388 pp., 2015.

Gerlitz, J. Y., Macchi, M., Brooks, N., Pandey, R., Banerjee, S., and Jha, S. K.: The Multidimensional Livelihood Vulnerability Index – an instrument to measure livelihood vulnerability to change in the Hindu Kush Himalayas, Clim. Dev, 9(2), 124-140, doi: 10.1080/17565529.2016.1145099, 2016.

Goodrich, C. G., Prakash, A., and Udas, P. B.: Gendered vulnerability and adaptation in Hindu-Kush Himalayas: Research insights, Environ. Dev., 31, 1-8, https://doi.org/10.1016/j.envdev.2019.01.001, 2018.

Gautam, M. R., Timilsina, G. R., and Acharya, K.: Climate Change in the Himalayas: Current State of Knowledge, World Bank Policy Research Working Paper No. 6516, SSRN, 64 pp., 2013.

Gaur, V. S., and Kotru, R.: Sustainable Tourism in the Indian Himalayan Region, Report of Working Group II, NITI Aayog-Government of India, India, 100 pp., 2018.

Hackl, J., Adey, B. T., and Heitzler, M.: An Overarching Risk Assessment Process to Evaluate the Risks Associated with Infrastructure Networks due to Natural Hazards, Int. J. Perform. Eng., 11(2), 153-168, doi: 10.23940/ijpe.15.2.p153.mag, 2015.

IS-code13828-1993: Indian Standard Improving Earthquake Resistance of Low Strength Masonry Buildings-Guidelines, Indian Standard Codes- guidelines, Bureau of Indian Standards, New Delhi, 22 pp., https://archive.org/details/gov.law.is.13828.1993, 2008.

IS-code13935-2009: Indian Standard Seismic Evaluation, Repair And Strengthening Of Masonry Buildings-Guidelines (First Revision), Indian Standard Codes- guidelines, Bureau of Indian Standards, New Delhi, 44 pp., https://archive.org/details/gov.in.is.13935.2009, 2009.

IS-code1893(1)2002: Indian Standard Criteria for Earthquake Resistant Design of Structures Part 1 General Provisions and Buildings (Fifth Revision), Indian Standard Codes- guidelines, Bureau of Indian Standards, New Delhi, 45 pp., https://archive.org/details/gov.in.is.1893.1.2002, 2002.

IS-code1893(1)2016: Indian Standard Criteria for Earthquake Resistant Design of Structures Part 1 General Provisions and Buildings (Fifth Revision), Indian Standard Codes- guidelines, Bureau of Indian Standards, New Delhi, 44 pp., https://archive.org/details/1893Part12016, 2016.

IS-code4326-1993: Indian Standard Earthquake Resistant Design and Construction of Buildings - Code of Practice (Second Revision), Indian Standard Codes- guidelines, Bureau of Indian Standards, New Delhi, 41 pp., https://archive.org/details/7.Is.4326.1993, 1993.

Jain, S. K., Mitra, K., Kumar, M., and Shah, M.: A Rapid Visual Seismic Assessment Procedure for RC Frame buildings in India, in: Proceedings of the 9th U.S. National and 10th Canadian Conference on Earthquake Engineering, Toronto, Ontario, Canada, 25-29 June 2010, Paper No 972, doi: 10.13140/2.1.2285.0884, 2010.

Kala, C. P.: Deluge , disaster and development in Uttarakhand Himalayan region of India-Challenges and lessons for disaster management, Int. J. Disaster Risk Reduct., 8, 143-152, doi: 10.1016/j.ijdrr.2014.03.002, 2014.

Khattri, K. N., Rogers, A. M., Perkins, D. M., and Algermissen: 'A seismic hazard map of india and adjacent areas', Tectonophysics, 108(1–2), 93–108, 111–134. doi: https://doi.org/10.1016/0040-1951(84)90156-2., 1984.

Kumar, S. A., Rajaram, C., Mishra, S., Kumar, R. P., and Karnath, A.: Rapid visual screening of different housing typologies in Himachal Pradesh, India, Nat Hazards, 85(3), 1851-1875, doi: 10.1007/s11069-016-2668-3, 2016.

Mohapatra, A. K., and Mohanty, W. K.: An Overview of Seismic Zonation Studies in India, in: Indian Geotechnical Conference, GEOtrendz, 16–18 December 2010, 175-178, 2010.

Marcussen, E.,: Explaining the 1934 Bihar-Nepal Earthquake : The Role of Science , Astrology , and " Rumours" In: Schenk, G. (eds) Historical Disaster Experiences. Transcultural Research – Heidelberg Studies on Asia and Europe in a Global Context. Springer, Cham., 241-266, doi: 10.1007/978-3-319-49163-9, 2017.

Map of India: https://www.mapsofindia.com/maps/india/seismiczone.htm, last access: 16 January 2022., 2021.

MHA-Ministry of Home Affairs: https://www.mha.gov.in/division_of_mha/disaster-management-division, last access: 16 July 2022., 2011.

Mouri, G., Minoshima, D., Golosov, V., Chalov, S., Seto, S., Yoshimura, K., Nakamura, S., and Oki, T.: Probability assessment of flood and sediment disasters in Japan using the Total Runoff-Integrating Pathways model, Int. J. Disaster Risk Reduct., 3, 31-43, https://doi.org/10.1016/j.ijdrr.2012.11.003, 2013.

NDMA: A Primer on Rapid Visual Screening (RVS) Consolidating Earthquake Safety Assessment Efforts in India, Manual and Guidelines, National Disaster Management Authority, Government of India, India, 75 pp., 2020.

NITI Aayog: Report of Working Group II Sustainable Tourism in the Indian Himalayan Region https://www.niti.gov.in/writereaddata/files/document_publication/Doc2.pdf. Last access: 25 January 2022., 2018.

NMHS- National Mission on Himalayan Studies: https://nmhs-himal.res.in/login.php, last access: 16 July 2022., 2019.

Parajuli, A., Gautam, A. P., Sharma, S. P., Bhujel, K. B., Sharma, G., Thapa, P. B., Bist, B. S., and Poudel, S.: Forest fire risk mapping using GIS and remote sensing in two major landscapes of Nepal, Geomatics, Nat. Hazards Risk., 11(1), 2569-2586, https://doi.org/10.1080/19475705.2020.1853251, 2020.

Pathak, R., Negi, V. S., Rawal, R. S., and Bhatt, I. D.: Alien plant invasion in the Indian Himalayan Region: state of knowledge and research priorities, Biodivers. Conserv., 28(12), 3073-3102, https://doi.org/10.1007/s10531-019-01829-1, 2019.

Peiris, T. A.: Flood Risk Assessment for Dungsum Chu Basin in Samdrup Jonkhar, Data Collection Report, Climate Technology Centre and Network (CTCN) and Asian Institute of Technology (AIT), Bhutan, 33 pp., 2015.

Rehman, A., Song, J., Haq, F., Mahmood, S., Ahamad, M. I., Basharat, M., and Mehmood, M. S.: Multi-Hazard Susceptibility Assessment Using the Analytical Hierarchy Process and Frequency Ratio Techniques in the Northwest Himalayas, Pakistan, Int. J. Remote Sens, 14(3)-554, 1-31, https://doi.org/10.3390/rs14030554, 2022.

Roopa, S., and Rani, M.: Questionnaire Designing for a Survey, Journal of Indian Orthodontic Society, 46(4), 273-277, doi: 10.1177/0974909820120509s, 2012.

Sanam, K. A., Lynn, M. R., Luke, j., and Laurence, W. C. Jr.: A geospatial analysis of multi-hazard risk in Dharan, Nepal, Geomatics, Nat. Hazards Risk., 11(1), 88-111, https://doi.org/10.1080/19475705.2019.1710580, 2020.

Sarkar, S., Kanungo, D. P., and Sharma, S.: Landslide hazard assessment in the upper Alaknanda valley of Indian Himalayas, Geomatics, Nat. Hazards Risk., 6(4), 308-325, http://dx.doi.org/10.1080/19475705.2013.847501, 2015.

Sekhri, S., Kumar, P., Fürst, C., and Pandey, R.: Mountain specific multi-hazard risk management framework (MSMRMF): Assessment and mitigation of multi-hazard and climate change risk in the Indian Himalayan Region, Ecol. Indic., 118, 106700, doi: 10.1016/j.ecolind.2020.106700, 2020.

Sharma, S., Roy, P. S., Chakravarthi, V., Srinivasarao, G., and Bhanumurthy, V.: Extraction of detailed level flood hazard zones using multi-temporal historical satellite data-sets – a case study of Kopili River Basin , Assam , India', *Geo Nat Hazards Risk*., 13(1), 2227-2251, doi: 10.1080/19475705.2016.1265014, 2017.

Siddique, M. I., Desai, J., Kulkarni, H., and Mahamuni, K.: Comprehensive report on Springs in the Indian Himalayan Region, Report number: ACWA/Hydro/2019/H88, Advanced Center for Water Resouces Development and Management, India, 198 pp., doi: 10.13140/RG.2.2.12104.06408, 2019.

Singh, J. S.: Sustainable development of the Indian Himalayan region: Linking ecological and economic concerns, Current Science, 90(6), 784–788, http://www.jstor.org/stable/24089189, 2005.

Singh, A., Kanungo, D. P. and Pal, S.: Physical vulnerability assessment of buildings exposed to landslides in India, Nat Hazards, 96(2), 753–790. doi: 10.1007/s11069-018-03568-y. 2019.

Sinha, R., and Goyal, A.: A National Policy for Seismic Vulnerability Assessment of Buildings and Procedure for Rapid Visual Screening of Buildings for Potential Seismic Vulnerability, Report, Indian Institute of Technology Bombay, Mumbai, 12 pp., 2001.

Srivastava, H. N., Verma, M., Bansal, B. K., and Sutar, A. K.: Discriminatory characteristics of seismic gaps in Himalaya, Geomatics, Nat. Hazards Risk., 6(3), 224-242, http://dx.doi.org/10.1080/19475705.2013.839483, 2015.

Srivastava, V., Srivastava, H. B., and Lakhera, R. C.: Fuzzy gamma based geomatic modelling for landslide hazard susceptibility in a part of Tons river valley, northwest Himalaya, India. Geomatics, Nat. Hazards Risk., 1(3), 225–242. doi:10.1080/19475705.2010.490103, 2010.

UNDRR.: https://www.undrr.org/terminology#R, last access: 30 January 2022.

URDPFI.: Urban and Regional Development Plans formulation and implementation (URDPFI) Guidelines, 1, Town and Country Planning Organization, Ministry of Urban Development, Government of India, 447 pp., 2015.

Wester, P., Mishra, A., Mukherji, A., & Shrestha, A. B. (Eds).:The Hindu Kush Himalaya Assessment, Springer Nature, Nepal, 627 pp., https://doi.org/10.1007/978-3-319-92288-1, 2019.