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

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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 test 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 enhanced 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, Landslide, High Wind, Industrial etc. The proposed form is self-explanatory, pictorial with easy terminologies, and is divided into various sections for better understanding of the surveyor etc.

The testing and validation 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

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1 Introduction

The Himalayan region is prone to disasters, due to its susceptibility to earthquakes, landslides, floods, wildfires etc. 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. 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, Narang and Mukherjee, 2022). 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). As environmental conditions continue to change, multihazard assessments are becoming increasingly crucial to communities.

One of the most challenging aspects of multi-hazard risk assessment (MHRA) is determining how to estimate the risk of several hazards in the same region and how they interact. 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 major significant role that directly or indirectly lead to an influence in correct assessment of the risk factor.

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 MHRA can lead to more robust strategies for disaster risk reduction (Kala, 2014; Sekhri *et al.*, 2020a) and can facilitate by prioritizing development planning decisions.

The foremost focus of the research described here is to critically review existing MHRA survey forms and their suitability for assessing risk for the IHR. A close evaluation of the existing survey questionnaires reveals that there is a need for the IHR-specific survey questionnaire form to facilitate a MHRA. In numerous accounts, this can help to optimize time and efforts required to document underlying components of risk in difficult hilly terrains, while improving the data quality.

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′. 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, Prakash and Udas, 2019; Sekhri *et al.*, 2020b). It stretches from the Indus River to the Brahmaputra River in the east. (Srivastava *et al.*, 2015). There are a total of 12 Indian Himalayan states and 1 Union territory as shown in Figure 1, which has 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

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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 dams across the region (Dharmadhikary, 2008). 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.*, 2020b).

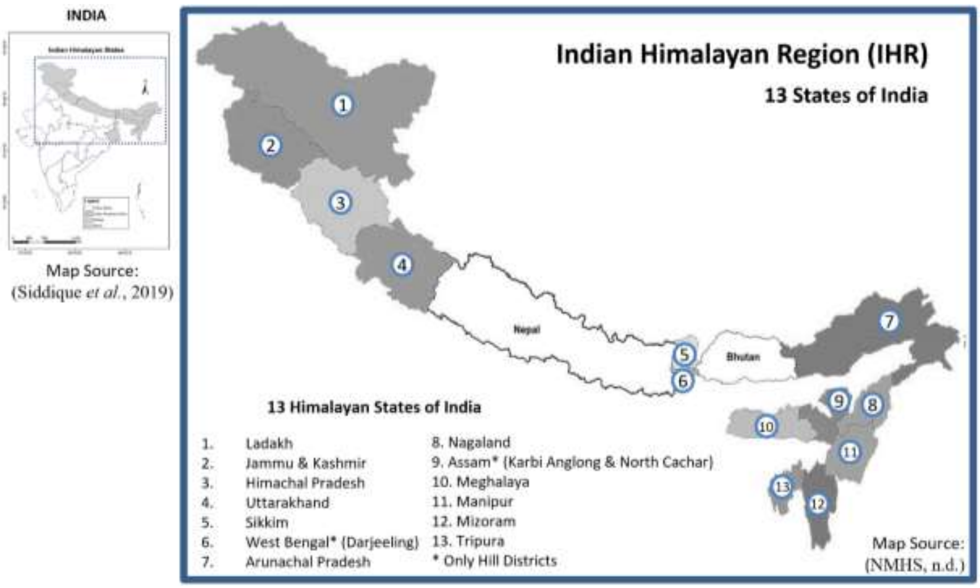

Figure 1: Indian Himalayan Region, Source: (NMHS, n.d.)(Mohammad Imran Siddique, Jayesh Desai, Himanshu Kulkarni, 2019)

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). The number of pilgrims has risen dramatically in prominent pilgrim centers across the Himalayas over the ages (Kala, 2014), putting undue strain 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 (Mahesh R. Gautam, Govinda R. Timilsina, 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 (Sv *et al.*, 2017). Mountain hazards are widespread, and hills characteristics are 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.*, 2020b).

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

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is determining how to estimate the risk of several hazards in the same region and how they interact (Hackl, Adey and Heitzler, 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 (Ministry of Home Affairs, 2011)(BMTPC, 2019). 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) and IMD

SN	Date	Location	Place	Indian Himalayan State	Hazard/Magnitude	Casualties	Source
1	1869 Jan 10th	(25.00, 93.00)	Nearcachar	Assam	Earthquake 7.5 Mw	Unknown	IMD
2	1885 May 30th	(34.10, 74.60)	Sopor	Jammu & Kashmir	Earthquake 7.0 Mw	Unknown	IMD
3	1897 Jun 12th	(26.00, 91.00)	Shillong plateau	Meghalaya	Earthquake 8.7 Mw	1500	IMD
4	1905 Apr 04th	(32.30, 76.30)	Kangra	Himachal Pradesh	Earthquake 8.0 Mw	19,000	IMD
5	1918 Jul 08th	(24.50, 91.00)	Srimangal	Assam	Earthquake 7.6 Mw	Unknown	IMD
6	1930 Jul 02nd	(25.80, 90.20)	Dhubri	Assam	Earthquake 7.1 Mw	Unknown	IMD
7	1943 Oct 23rd	(26.80, 94.00)	Assam	Assam	Earthquake 7.2 Mw	Unknown	IMD
8	1950 Aug 15th	(28.50, 96.70)	Arunachal Pradesh–China Border	Arunachal Pradesh	Earthquake 8.5 Mw	1526	IMD
9	1975 Jan 19th	(32.38, 78.49)	Kinnaur	Himachal Pradesh	Earthquake 6.2 Mw	Unknown	IMD
10	1988 Aug 06th	(25.13, 95.15)	Manipur–Myanmar border	Manipur	Earthquake 6.6 Mw	1000	IMD
11	1991 Oct 20th	(30.75, 78.86)	Uttarkashi, UP	Uttarakhand (now)	Earthquake 6.6 Mw	2000	IMD
12	1998 Aug 18th	(30.01, 80.04)	Malpa, Pithoragarh district	Uttarakhand (now)	Landslide	380	IMD
13	1999 Mar 29th	(30.41, 79.42)	Chamoli Dist, UP	Uttarakhand (now)	Earthquake 6.8 Mw	100	IMD
14	2005 Oct 08th	(34.48, 73.61)	Kashmir	Jammu & Kashmir	Earthquake 7.6 Mw	74,500	IMD
15	2006 Feb 14th	(27.37, 88.36)	Sikkim	Sikkim	Earthquake 5.7 Mw	No Casualty	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	IMD
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)	Uttarakhand	Uttarakhand	Flood, Landslide, Cloud Burst	5748	IMD
21	2014 Sep 13th	(33.27, 75.34)	Jammu & kashmir	Jammu & Kashmir	Flood, Cloud Burst	277	IMD

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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 on 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). An area of near 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 (Simon 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.*, 2020a) 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.*, 2020b). 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 (Aksha 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.*, 2020b).

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 (Vaidya *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.*, 2020b).

The comparative study of some of the most used survey form to assess risk in India in shown in the table 2. The detail of all the mentioned survey form will be explain later 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.

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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 (Enhanced)
Source: adapted from		Arya, 2006	FEMA, 2015	NDMA, 2020	Sinha, 2004	Pradesh, 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	✓	✓	✓	✓	✓		✓

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 few recommendations for designing a good survey form (Roopa and Rani, 2012) (QuestionPro, n.d.).

- It should satisfy the objectives of the research.
- The number of essential parts to be covered in the questionnaires with dictate length.
- Easily understood, Simple language and pictorial explanation for better understanding
- The survey response rate can be increased by using multiple-choice questions.
- A single thought should be conveyed at a time
- As much as possible, be concrete and conform to the respondent's perspective
- The use of unclear words should be avoided
- Survey Logic: In designing a survey, logic is among the most important factors. 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.

Its methodology involves selecting and analyzing a sample of individuals from a population and using various techniques for collecting data. It is used to collect data from a predetermined sample of respondents, process the data, and increase survey response rates (QuestionPro, n.d.).

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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. 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 figure 2.

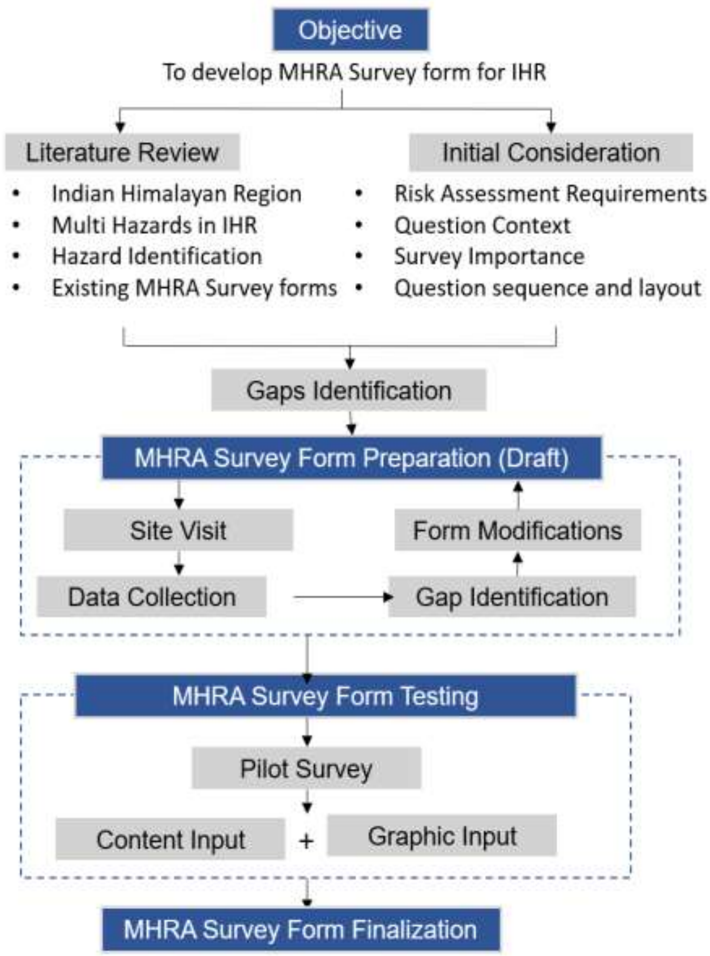

Figure 2: Methodology adopted

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

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do" (attributed to Francesca Valli, Change Management Thought-Leader), and as the detailed assessment is limited to 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 (Pradesh, Pradeep and Anoop, 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.) (Figure 3). Based on the damage earthquakes caused in various parts of India, this map has undergone numerous modifications since its original creation. India is divided into four distinct earthquake risk zones shown here by colour (Bilham and Laituri, 2003) in figure 3 below:

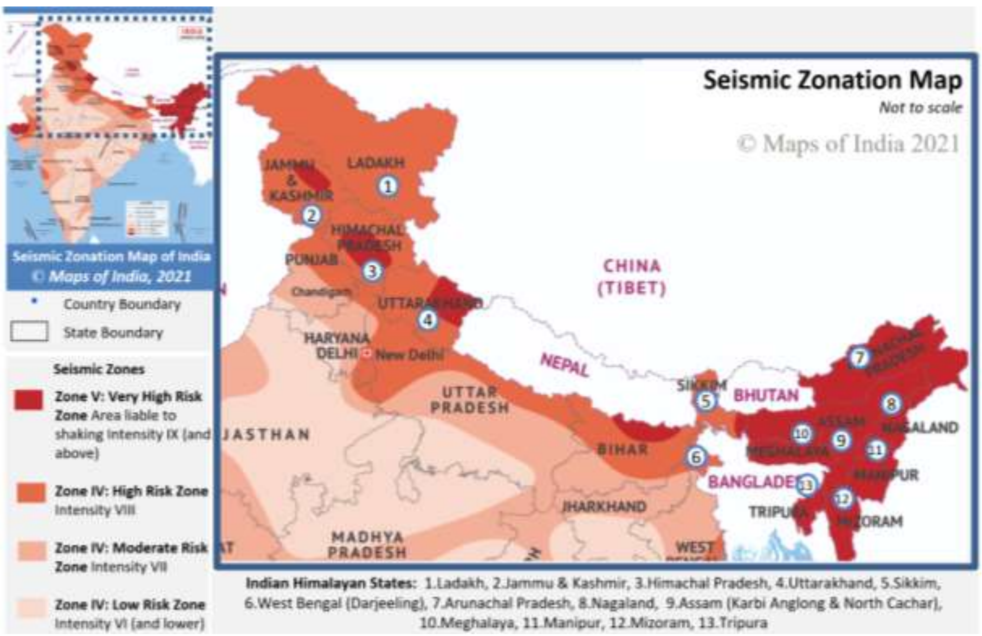

Figure 3: Seismic Zonation Map of India, Source: (India, n.d., p. Map of India)

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. (Pradesh, Pradeep and Anoop, 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, 2006b).

3.3.2.1 Uses of RVS Results:

The foremost uses of this technique concerning seismic advancement of existing buildings are:

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Assess a building's seismic vulnerability to categorize it further.

- 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, 2006b).

3.3.3 Uses of the Four Levels of Earthquake Safety Assessments

3.3.3.1 Level 1: Rapid Visual Screening (RVS)

The method does not require any structural calculations to be performed. For the purpose of identifying the main structural members that resist lateral loads and the characteristics of buildings that modify their performance during earthquakes, the evaluator applies a scoring system. On average, each building inspection, data collection, and decision-making takes about 30 minutes.

3.3.3.2 Level 2: Detailed Visual Study (DVS)

It can be used to assess a house as a first-level exercise before performing a detailed retrofit, and to assess the performance and safety of a house of a certain type.

3.3.3.3 Level 3: Simplified Vulnerability Assessment (SVA)

In comparison to RVS, the simplified vulnerability assessment (SVA) is more complex and therefore more precise. The technique uses engineering information for example the size and strength of lateral load resisting members, along with more explicit data on ground motion. By analyzing this information, the building drift is estimated using an extremely simplified breakdown. Based on a good correlation between drift and damage, the analysis can be used to quantify the potential seismic hazard of a building.

3.3.3.4 Level 4: Detailed Vulnerability Assessment (DVA)

To perform a DVA of a building, an engineering analysis must be conducted taking into account the non-linear behaviour of structural components and the potential impact of ground motions. The detailed vulnerability assessment procedure requires a very high level of engineering knowledge, skills, and experience.

3.3.4 Multi Hazard Risk Assessment used in India

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

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, 2006b) for detail RVS survey forms for masonry buildings prepared by Prof. A.S. Arya.

3.3.4.2 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,

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roof, floor, etc. (iii) Structural frame type (iv) Special Hazard (v) Non-Structural building components (vi) Damageable Grades (Arya, 2006a).

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) for detailed RVS Survey form for RC and steel buildings prepared by Prof. A.S. Arya.

3.3.4.3 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 (Sudhir K Jain, Keya Mitra, Manish Kumar, 2010).

3.3.4.4 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). Refer (NDMA, 2020) for detailed survey form.

3.3.4.5 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.

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. Refer (Ravi Sinha, 2001) for detailed survey form.

3.3.4.6 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 the paper titled Rapid visual screening of different housing types in Himachal Pradesh, India. 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 (RC frames, brick masonry, stone masonry, Rammed Earth, and hybrid). (Pradesh, Pradeep and Anoop, 2016). Refer (Pradesh.et.at. 2019) for Building Vulnerability form developed by HPSDMA & TARU.

3.3.4.7 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. It was hailed as an "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 Figure 4 shows different Housing categories 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

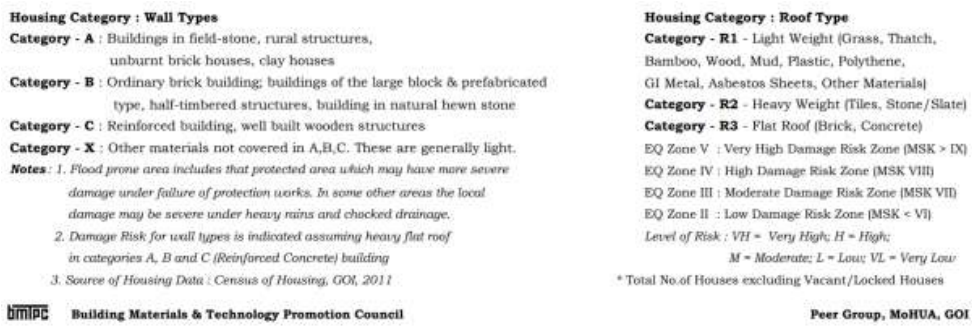

Figure 4: Damage Risk and Housing category identified by BMTPC (BMTPC, 2019)

3.3.5 Multi Hazard Risk Assessment used Globally

3.3.5.1 FEMA 154

The FEMA handbook demonstrates how to rapidly identify, inventories, and rank buildings that are at high risk of 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). Refer (FEMA, 2015) for detail survey form .

3.3.5.2 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, designed for Residential, Institutional, Commercial/Industrial damages and Infrastructure damages. Refer (Singh, Kanungo and Pal, 2019) for Flood Vulnerability Assessment Survey form developed by CTCN and AIT

3.3.5.3 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 cover by Landslide risk assessment survey forms (Singh, Kanungo and Pal, 2019) are (i) General information (ii) Building Function (iii) Vulnerability Indicators like Architectural Features, Material

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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

As a result of a collaboration between Departments of Geomatics Engineering and Geological Engineering, Hacettepe University has created the CitiSci platform for geoscience research. A WebGIS platform supported by CitSci and artificial intelligence (AI) was used in this study to assist landslide researchers. Data visualization and display software is incorporated in the WebGIS application, mobile data collection software (LaMA), and an AI system controls the quality control process for data (R. Can, 2020).

3.4 Features required for a Multi Hazard Survey Form for IHR

3.4.1 Gaps Identified

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 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 and DVA 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 is buildings for its location is from 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

Here is the comparative analysis of Risk assessment survey forms developed by various organizations and mostly used in India with the enhanced Multi-Hazard RVS. It has 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 (Enhanced)
Source		Arya, 2006	FEMA, 2015	NDMA , 2020	Sinha, 2004	Pradesh, 2016	BMTPC, 2019	Author
Typology	A1: Mud & Unburnt Brick			✓	✓		✓	✓

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	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			✓				✓

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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							✓

4 IHR Specific MHRA Survey Form Preparation

4.1 Survey Form Preparation

The enhanced survey form is a modification of the Uttarakhand 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. No other hazards are considered in the original RVS questionnaire. 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 enhanced form to identify the risk components from multi-hazards. Whilst the Himalayan region is prone to earthquakes as per India's Seismic Zonation Map (Figure 3) prepared by the Geographical Survey of India (GSI), the enhanced survey form also covers other hazards like landslide, flood, industrial explosion/emissions, fire, hydro-climatic factors, etc., which will be addressed one by one in this paper.

4.2 Pilot Survey

Before conducting the final survey, a preliminary survey has been conducted to test the proposed form, research methodology, and identifying gaps in the existing survey form (S Roopa1, 2019).

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This small assessment also evaluated the RVS form with minor enhancements 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 Pilot survey had been conducted at 5 Gram Panchayats of Chinyalisaur sub-district in Uttarkashi, Uttarakhand, namely Chinyalisaur, Dhanpur, Dharasu, Hidhara, and Bagi, in October and November 2019. Some of the pictures of the visit are provided in Figure 5.

Figure 5: View of Site selected for Pilot Survey

The pilot survey was conducted to determine:

- Whether the questions are clearly framed?
- Does it cover all the requirements as per hill communities?
- Is the wording of the questions correct enough to lead to the desired outcomes?
- Is the question as well options for answer suggested is hill specific or not?
- Is the question positioned is in the most satisfactory order?
- Surveyors and respondents of all classes understand the questions?
- The questions and their options are self-explanatory or not?
- The sections in the survey form cover risk assessment related questions for all identified hazards or not
- The questions are as per construction practices and construction materials available on hills or not?

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- Are there any need to add some Questions or specified, or some need to be eliminated so as to mention the flow of the survey session.
- Does surveyor and Respondent understand the importance of this survey or the objective behind this survey and response in that way?

4.2.1 Observations during Pilot survey

Feedback from the pilot study proved very helpful in determining the key gaps and shortcomings of the form design and in informing improvements to the enhanced form design. Specifically:

- The pilot 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.
- 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.
- The questionnaire may not be self-explanatory and requires someone with civil engineering training to fill it out.
- Building geometric, Construction practices, Construction materials, development trend plays an essential role during any hazard, thus existing building related questions and options must be incorporated
- Survey questions are developed primarily from observations made by surveys and engineers as opposed to responses from residents.
- If the Surveyor is not familiar with the terminologies and aims behind filling that questionnaire, it leads to no response or respondent sometimes loose interest to answer further.
- 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.
- Surveyors should be trained enough to pick out the correct option from respondents' lengthy responses.
- Need of pictorial representation of answers/options for better understanding of the Surveyor.
- Different answers are obtained when questions are arranged inappropriately or answers are arranged incorrectly.
- Observing the interaction between multiple hazard types in the same area is a challenging aspect of natural hazards risk assessment.

4.3 Enhanced MHRA Form

After the Pilot survey conducted at the Chinyalisaur sub-district, significant points were identified/observed that has been incorporated in the Enhanced survey form of Multi-Hazard at hill locations for better risk assessment results. 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: Enhanced 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	

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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)	Commercial (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		

Table 5b: Enhanced MHRA Survey form (Part A)

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?					

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SITE CONDITION					
31	Location of Building:	Isolated (House)	Internal Corner (H)		End (H)
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) :				

Table 5c: Enhanced MHRA Survey form (Part A)

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

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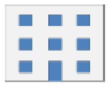
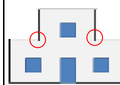
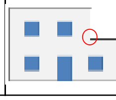
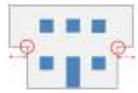
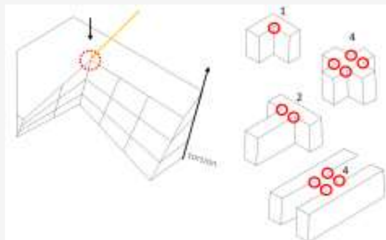
38	Shape of building Block in Elevation: No. of Reentrants corner in Plan	Not stepped	Stepped near centre	Stepped near the end	Heavy upper floor	
						
39	No. of Reentrants corner in Plan					
40	Is extra strength available in reentrants corner?	Yes		No		
41	No. of Floors	only G	G+1	G+2	G+3	> G+4

Table 5d: Enhanced MHRA Survey form (Part A)

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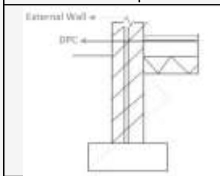
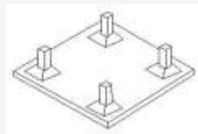
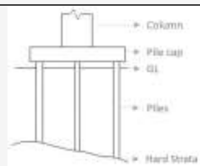
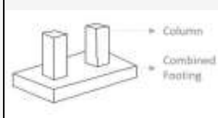
FOUNDATION					
42	Type of Sub Soil:	Rock	Gravel or Sand	Soft or Medium	Other
					
43	Type of Foundation:	Strip	Raft	Isolated	
					
		Pile	Combined	Other	
					

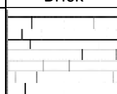
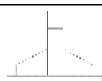
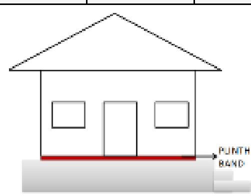
44	Basic Construction material of Foundation:	Adope	Stone	Brick	RCC	Other
						
45	Mortar Material in Foundation:	Dry Masonry	Mud	Lime	Cement	Other
46	Plinth beam available?	Yes	No			
47	Sinking in Foundation?	Yes		Partial	No	
48	If Yes or Partial in Q.47, What is the Reason for Sinking?	Cause of nearest water resources		Without any water resources		Other (specify)
49	Depth of ground water table					Don't know

Table 5e: Enhanced MHRA Survey form (Part A)

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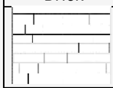
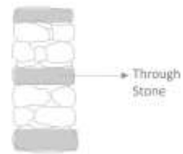
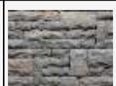
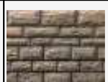
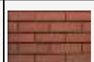
WALL						
50	Type of Wall:	Brick	Stone	Confined	RCC	Other
				Only Column available & No Beams	Column & Beam, both available	
51	Is through-stone used in Stone Wall?	Yes	Partial	No		
52	What is the Wall material?	Adobe or Mud Wall	River Boulder wall	Quarry Stone wall	Dressed wall	fired brick wall
						
		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					

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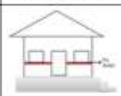
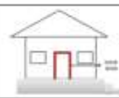
Table 5f: Enhanced MHRA Survey form (Part A)

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

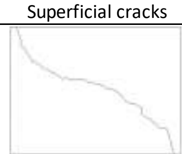
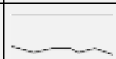
CRACKS						
63	Type of Cracks:	Structural cracks		Superficial cracks		N/A
	Note: Superfial cracks are seen in one side of wall, on the other hand structural cracks can be seen on both side of the wall					
64	Type of Structural cracks:	Diagonal cracks	Vertical cracks	Horizontal Cracks	Remark	
						
	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

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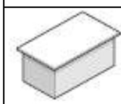
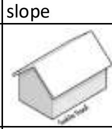
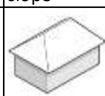
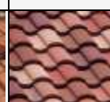
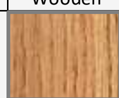
Table 5g: Enhanced MHRA Survey form (Part A)

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	

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

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

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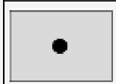
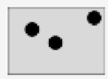
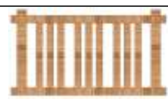
Table 5h: Enhanced MHRA Survey form (Part A)

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	

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	

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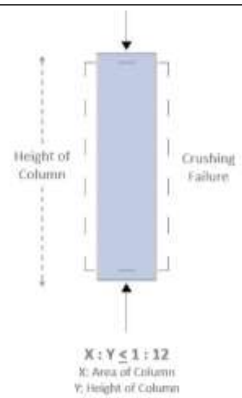
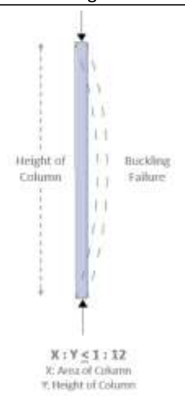
Table 5i: Enhanced MHRA Survey form (Part A)

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

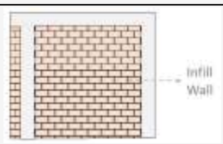
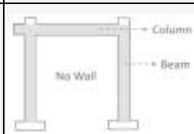
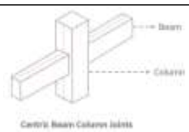
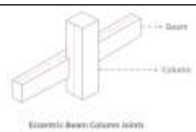
BEAM						
100	Beam available?	Yes			No	
101	If Yes in Q.100., Beam with infill walls available?	Yes		Partial	No	
						
102	If Yes in Q.100., Beam – Column connections?	Centric		Eccentric		Other
						
103	Beam -Beam Connection?	Centric		Eccentric		Other
104	If Yes in Q.100., Material of Beam	Concrete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

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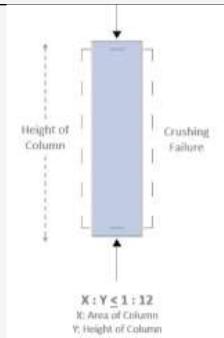
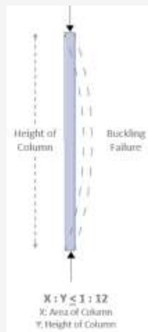
Table 5j: Enhanced MHRA Survey form (Part A)

<table>
<tr><th colspan="6">BASEMENT</th></tr>
<tr><td rowspan="2">105</td><td rowspan="2">Is Basement Available?</td><td colspan="3">Yes</td><td>No</td></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><td>106</td><td>If Yes in Q.105, No. of Basement</td><td colspan="4"></td></tr>
<tr><td rowspan="3">107</td><td rowspan="3">Effective height of column in basement?</td><td colspan="3">Short Column</td><td>Long Column</td></tr>
<tr><td colspan="3">
</td><td>
</td></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><td rowspan="2">108</td><td rowspan="2">Retaining wall available ?</td><td colspan="3">Yes</td><td>No</td></tr>
<tr><td colspan="3"></td><td></td></tr>
<tr><td rowspan="2">109</td><td rowspan="2">If Yes in Q.108, What is the Material of the retaining wall ?</td><td>RCC</td><td>Brick</td><td>Stone</td><td>Other</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

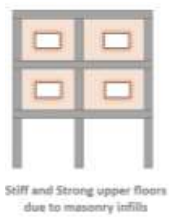
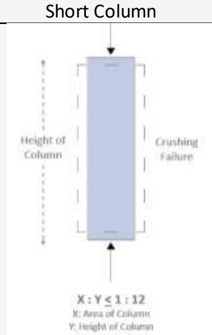
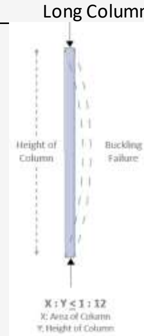
<table>
<tr><th colspan="5">SOFT STOREY</th></tr>
<tr><td></td><td>A soft story building is a multi-story building in which one or more floors have windows, wide doors, large unobstructed commercial spaces, or other openings in places where a shear wall would normally be required for stability as a matter of earthquake engineering design.</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td rowspan="2">110</td><td rowspan="2">Soft Storey available ?</td><td colspan="2">Yes</td><td>No</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td rowspan="3">111</td><td rowspan="3">Effective height of column in basement?</td><td colspan="2">Short Column</td><td>Long Column</td></tr>
<tr><td colspan="2">
</td><td>
</td></tr>
<tr><td colspan="2"></td><td></td></tr>
</table>

Table 5k: Enhanced MHRA Survey form (Part A)

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
MULTI HAZARD SURVEY FORM					

Table 6a: Enhanced 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					
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

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

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	

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

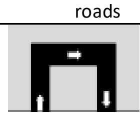
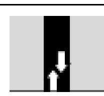
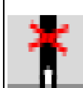
FIRE					
21	Are the access roads from main street wide enough to allow one fire engine to reach, reverse and return to the main road?	two or more such access roads		one such access road	No access road
					
22	Are there potential fire threats within 30 meters of the building such as petrol pump, electrical 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	

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Table 6b: Enhanced MHRA Survey form (Part B)

25	Are the main meter box and switch box enclosed in a metallic box?	Yes			No	
26	Is there more than 1 staircase which can be used as a fire escape staircase ideally at maximum distance from the other staircase?	Yes			No	
27	In case of Public building or Life line building, Are there proper signages in the campus for Emergency Exit, Fire equipment etc.?	Yes 			No	
28	Is the kitchen located at a safe distance from classrooms, staircase, passage corridor?	Yes, beyond 50 m	Yes, within 20-50 m	Yes, within 10-20 m	adjacent	Kitchen Not Available
29	Is the ceiling material safe from fire?	Yes			No	
30	What is the status of fire safety equipment in the building?	100% - Fire extinguisher in each floor of each block	75% - Fire extinguisher in 3/4th of all floors	50% - Fire extinguisher in half of all floors	25% - Fire extinguisher in 1/4th of all floors	0% - No Equipment

31	Is the transformer too close to the compound wall or inside the building?	Yes	No
32	Are there overhead cables running through or near premises/building?	Yes	No
33	If there is a forest area near the building?	Yes	No
34	What is the distance of the tree line from the building?		
35	Is there any combustible construction material present in the building?	Yes	No

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Table 6c: Enhanced MHRA Survey form (Part B)

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
		Industrialization	Melting of Ice	Warming of water surface	Other	Don't know

Non Structural Risk/ Falling Hazard							
1	List of Nonstructural elements which are vulnerable to falling or not attached properly	*Element*	*Need Attention*	*Number*	*Element*	*Need Attention*	*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		
2	No. of Exits in the Room:						
3	What is the status of Electrical Safety in the Room	GOOD			OK		POOR

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4.4 Risk Score Computation

After all the parametric studies from various Indian Standard codes and Report (NDMA, 2020), (URDPFI, 2015) (IS-code13828, 1993; IS-code4326, 1993; IS-code1893-1, 2002; IS-code13935, 2009) on ideal building parameters and weak components of a building from designing, construction, site condition, surrounding condition, location and hazard etc. point of views, risk scores were decided on an average basis for better judgment and understanding. Risk scores were derived from the enhanced survey form by appropriately weighing the data points against a risk number chart with higher weightage given to higher risk (Chouhan, Narang and Mukherjee, 2022). The data was then aggregated on a scale of ten (table 8). For example, if a building answers all weighted MCQs with the highest risk option, it will be scored 10/10. 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 building to enable prioritization during risk mitigation planning.

Table 7: Risk Score Computation, Source adapted from (Chouhan, Narang and Mukherjee, 2022)

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

5 Discussion:

5.1 Pilot Survey Results

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 enhanced 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 enhanced 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, Wind, Industrial, Non-Structural Risk., fire etc. It 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, 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

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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 is 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 covers the non-structural risk survey form. 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.

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. 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 state. Thus, safety is the immense need of the government at various levels.

The enhanced survey form designed and tested under this study will help all the stakeholders to collect better information from the field. This form will also identify the weak components of a building, construction practices, their development trend, and vulnerable 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. The more accurate the data, the better will be its results.

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, and tailored specifically for hill communities.

The pilot survey conducted at Chinyalisaur validates the questionnaire and survey form, and provided invaluable feedback now incorporated in to the final survey form design.

The proposed form is a self-explanatory, pictorial, and enhanced version of the standard RVS format, and it addresses several hazards such as earthquakes, floods, landslides, industrial fires, and forest fires.

The suggested form is an enhanced 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. Research is being undertaken to develop more accurate hill-specific risk assessment survey form that requires less time, marginal effort. identify deficiencies and, most important suggest a site-specific Multi-Hazard Survey form for hills.

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.

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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

Aksha, S. K. *et al.* (2020) 'A geospatial analysis of multi-hazard risk in', *Geomatics, Natural Hazards and Risk*. Taylor & Francis, 11(1), pp. 88–111. doi: 10.1080/19475705.2019.1710580.

Arya, A. S. (2006a) *Rapid Visual Screening of RCC Buildings*. Available at: https://nidm.gov.in/PDF/safety/earthquake/link11.pdf.

Arya, A. S. (2006b) 'Rapid Visual Svreening of Masonry Buildings', *GOI – UNDP Disaster Risk Management Programme*, 13935(June), pp. 17–41. Available at: https://nidm.gov.in/PDF/safety/earthquake/link11.pdf.

Bilham, R. and Laituri, M. (2003) 'Earthquake Loss Estimation for India Based on Macroeconomic Indicators', (April 2016). doi: 10.1007/978-94-010-0167-0.

BMTPC (2019) *Vulnerability Atlas of India Vulnerability Atlas of India*. 3rd edn. Available at: https://bmtpc.org/DataFiles/CMS/file/Publication/VAI_3rd2019.pdf.

Buck, K. D. and Summers, J. K. (2020) 'Application of a multi-hazard risk assessment for local planning local planning', *Geomatics, Natural Hazards and Risk*. Taylor & Francis, 11(1), pp. 2058–2078. doi: 10.1080/19475705.2020.1828190.

Chandel, V. B. S. and Brar, K. K. (2010) 'Seismicity and vulnerability in Himalayas : the case of Himachal Pradesh , India', *Geomatics, Natural Hazards and Risk*, 5705. doi: 10.1080/19475701003643441.

Chouhan, S., Narang, A. and Mukherjee, M. (2022) 'Multihazard risk assessment of educational institutes of',

https://doi.org/10.5194/nhess-2022-91
Preprint. Discussion started: 26 April 2022

International Journal of Disaster Resilience in the Built Environment. doi: 10.1108/IJDRBE-08-2021-0091.

Dharmadhikary (2008) *Mountains of Concrete : Dam Building in the Himalayas*. Available at: https://archive.internationalrivers.org/sites/default/files/attached-files/ir_himalayas_rev.pdf.

FEMA (2015) *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*. Available at: https://www.fema.gov/sites/default/files/2020-07/fema_earthquakes_rapid-visual-screening-of-buildings-for-potential-seismic-hazards-a-handbook-third-edition-fema-p-154.pdf.

Gerlitz, J. *et al.* (2016) 'The Multidimensional Livelihood Vulnerability Index – an instrument to measure livelihood vulnerability to change in the Hindu Kush Himalayas', *Climate and Development*, 9 (2)(March), pp. 124–140. doi: 10.1080/17565529.2016.1145099.

Goodrich, C. G., Prakash, A. and Udas, P. B. (2019) 'Gendered vulnerability and adaptation in Hindu-Kush Himalayas: Research insights', *Environmental Development*. Elsevier Ltd, 31(January), pp. 1–8. doi: 10.1016/j.envdev.2019.01.001.

Hackl, J., Adey, B. T. and Heitzler, M. (2015) 'An Overarching Risk Assessment Process to Evaluate the Risks Associated with Infrastructure Networks due to Natural Hazards', *International Journal for Performability Engineering*, 11(2), pp. 153–168. doi: 10.23940/ijpe.15.2.p153.mag.

IS-code13828 (1993) *Indian Standard IMPROVING EARTHQUAKE RESISTANCE OF LOW STRENGTH MASONRY BUILDINGS — GUIDELINES*. Available at: https://law.resource.org/pub/in/bis/S03/is.13828.1993.pdf.

IS-code13935 (2009) *Indian Standard SEISMIC EVALUATION, REPAIR AND STRENGTHENING OF MASONRY BUILDINGS — GUIDELINES (First Revision)*. Available at: https://law.resource.org/pub/in/bis/S03/is.13935.2009.pdf.

IS-code1893-1 (2002) *Indian Standard CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES PART 1 GENERAL PROVISIONS AND BUILDINGS (Ffth Revision)*. Available at: https://law.resource.org/pub/in/bis/S03/is.1893.1.2002.pdf.

IS-code4326 (1993) *Indian Standard EARTHQUAKE RESISTANT DESIGN AND CONSTRUCTION OF BUILDINGS - CODE OF PRACTICE (Second Revision)*. Available at: https://civil.sairam.edu.in/wp-content/uploads/sites/4/2019/06/IS.4326.1993.pdf.

Kala, C. P. (2014) 'International Journal of Disaster Risk Reduction Deluge , disaster and development in Uttarakhand Himalayan region of India : Challenges and lessons for disaster management', *International Journal of Disaster Risk Reduction*. Elsevier, 8, pp. 143–152. doi: 10.1016/j.ijdrr.2014.03.002.

Mahesh R. Gautam, Govinda R. Timilsina, K. A. (2013) *Climate Change in the Himalayas Current State of Knowledge*. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2286555.

Ministry of Home Affairs, G. (2011) *DISASTER MANAGEMENT Ministry of Home Affairs*. Available at:

https://doi.org/10.5194/nhess-2022-91
Preprint. Discussion started: 26 April 2022

https://www.undp.org/content/dam/india/docs/disaster_management_in_india.pdf.

Mohammad Imran Siddique, Jayesh Desai, Himanshu Kulkarni, K. M. (2019) *Comprehensive report on Springs in the Indian Himalayan Region*. doi: 10.13140/RG.2.2.12104.06408.

Mouri, G. *et al.* (2013) 'International Journal of Disaster Risk Reduction Probability assessment of flood and sediment disasters in Japan using the Total Runoff-Integrating Pathways model', *International Journal of Disaster Risk Reduction*. Elsevier, 3, pp. 31–43. doi: 10.1016/j.ijdrr.2012.11.003.

NDMA (2020) *A Primer on Rapid Visual Screening (RVS) Consolidating Earthquake Safety Assessment Efforts in India*. Available at: https://ndma.gov.in/sites/default/files/PDF/Technical Documents/RVS-Doc-11-2020.pdf.

NITI Aayog (2018) *Report of Working Group II Sustainable Tourism in the Indian Himalayan Region*. Available at: https://www.niti.gov.in/writereaddata/files/document_publication/Doc2.pdf.

Parajuli, A. *et al.* (2020) 'Forest fire risk mapping using GIS and remote sensing in two major landscapes of Nepal', *Geomatics, Natural Hazards and Risk*. Taylor & Francis, 11(1), pp. 2569–2586. doi: 10.1080/19475705.2020.1853251.

Pathak, R. *et al.* (2019) 'Alien plant invasion in the Indian Himalayan Region : state of knowledge and research priorities', *Biodiversity and Conservation*. Springer Netherlands, (0123456789). doi: 10.1007/s10531-019-01829-1.

Peiris, T. A. (2015) *Data collection for " Flood Risk Assessment for Dungsum Chu Basin in Samdrup Jonkhar "*, *CTCN and AIT*. Available at: https://www.ctc-n.org/system/files/dossier/3b/ctcn_bhutan_data_collection_report.pdf.

Pradesh, H., Pradeep, R. and Anoop, K. (2016) 'Rapid visual screening of different housing typologies', *Natural Hazards*. Springer Netherlands. doi: 10.1007/s11069-016-2668-3.

Ravi Sinha, A. G. (2001) *A National Policy for Seismic Vulnerability Assessment of Buildings and Procedure for Rapid Visual Screening of Buildings for Potential Seismic Vulnerability*. Available at: https://www.civil.iitb.ac.in/~rsinha/Vulnerability_Assessment.pdf.

Rehman, A. *et al.* (2022) 'Multi-Hazard Susceptibility Assessment Using the Analytical Hierarchy Process and Frequency Ratio Techniques in the Northwest Himalayas , Pakistan', *Remote Sens*, 14(3), pp. 1–31. doi: https://doi.org/10.3390/rs14030554.

Roopa, S. and Rani, M. (2012) 'Questionnaire Designing for a Survey', *Journal of Indian Orthodontic Society*, 46(4_suppl1), pp. 273–277. doi: 10.1177/0974909820120509s.

Sarkar, S., Kanungo, D. P. and Sharma, S. (2015) 'Landslide hazard assessment in the upper Alaknanda valley of Indian Himalayas', *Geomatics, Natural Hazards and Risk*. Taylor & Francis, 6(4), pp. 308–325. doi: 10.1080/19475705.2013.847501.

Sekhri, S. *et al.* (2020a) 'Mountain speci fi c multi-hazard risk management framework (MSMRMF): Assessment

https://doi.org/10.5194/nhess-2022-91
Preprint. Discussion started: 26 April 2022

and mitigation of multi-hazard and climate change risk in the Indian Himalayan Region', *Ecological Indicators*. Elsevier, 118(July), p. 106700. doi: 10.1016/j.ecolind.2020.106700.

Sekhri, S. *et al.* (2020b) 'Mountain specific multi-hazard risk management framework (MSMRMF): Assessment and mitigation of multi-hazard and climate change risk in the Indian Himalayan Region', *Ecological Indicators*. Elsevier, 118(April), p. 106700. doi: 10.1016/j.ecolind.2020.106700.

Simon Allen, M. A. (2015) 'Lake outburst and debris flow disaster at Kedarnath , June 2013 : hydrometeorological triggering and topographic predisposition Lake outburst and debris flow disaster at Kedarnath , June 2013 : hydrometeorological triggering and topographic predisposition', *Landslides*, 13(6). doi: 10.1007/s10346-015-0584-3.

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

Singh, J. S. (2005) 'Sustainable development of the Indian Himalayan region: Linking ecological and economic concerns', *Current Science*, 90(6), pp. 784–788.

Srivastava, H. N. *et al.* (2015) 'Discriminatory characteristics of seismic gaps in Himalaya', *Geomatics, Natural Hazards and Risk*. Taylor & Francis, 6(3), pp. 224–242. doi: 10.1080/19475705.2013.839483.

Srivastava, V., Srivastava, H. B. and Lakhera, R. C. (2010) 'Fuzzy gamma based geomatic modelling for landslide hazard susceptibility in a part of Tons river valley , northwest Himalaya , India', *Geomatics, Natural Hazards and Risk*, 5705. doi: 10.1080/19475705.2010.490103.

Sudhir K Jain, Keya Mitra, Manish Kumar, M. S. (2010) 'A rapid visual seismic assessment procedure for RC frame buildings in India', in *9th U.S. National and 10th Canadian Conference on Earthquake Engineering*. doi: 10.13140/2.1.2285.0884.

Sv, S. S. *et al.* (2017) 'Extraction of detailed level flood hazard zones using multi-temporal historical satellite data-sets – a case study of Kopili River Basin , Assam , India', *Geomatics, Natural Hazards and Risk*. Taylor & Francis, 5705. doi: 10.1080/19475705.2016.1265014.

URDPFI (2015) *Urban and Regional Development Plans formulation and implementation (URDPFI) Guidelines*. Available at: https://mohua.gov.in/upload/uploadfiles/files/URDPFI Guidelines Vol I.pdf.

Vaidya, R. A. *et al.* (2019) *Disaster Risk Reduction and Building Resilience in the Hindu Kush Himalaya*. Springer International Publishing. doi: 10.1007/978-3-319-92288-1.