Sustainable Infrastructure Development, Risk Perception and Vulnerability Assessment in Indian Himalayan Region

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About the Series

This Working Paper Series is a new publication of Integrated Research on Disaster Risk (IRDR), following the decision of the IRDR Scientific Committee in April 2019 to act to 'Expand IRDR Network and Scientific Output' (No. 5 of the IRDR Action Plan 2018-2020).

IRDR is an international scientific programme under co-sponsorship of the International Science Council (ISC) and United Nations Office for Disaster Risk Reduction (UNISDR) and with support from China Association for Science and Technology (CAST) and Chinese Academy of Sciences (CAS). Started in 2010, the Programme has been pioneering in the promoting international and interdisciplinary studies on Disaster Risk Reduction (DRR) and has made its contributions through scientific publication and policy papers as well as dialogue toward shaping international agenda in the understanding disaster risks, bridging science and policy gaps and promoting knowledge for actions, all required in the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) and its top priorities. Over time, the scientific agenda of IRDR has attracted many international renowned expertise and institutions. IRDR community is now, institutionally speaking, characterized by its strong Scientific Committee and six thematic working groups, thirteen IRDR national committees (IRDR NCs) and one regional committee (IRDR RC), sixteen international centres of excellence (IRDR ICoEs), a group of some one hundred fifty Young Scientists (IRDR YS) and a broad partnership with national, regional and international institutions working for SFDRR.

This Working Paper Series is thus specially made to facilitate the dissemination of the work of IRDR NCs, ICoEs, YS and institutions and individual experts that IRDR considers relevant to its mission and research agenda, and of important values for much broader range of audience working in DRR domains. As one will notice, all working papers in this series has anchored their relevance and contributions of their work toward SFDRR, IRDR, Sustainable Development Goals (SDGs) and Paris Agreement on climate change. It is the hope of the authors of the working papers and IRDR that this working paper series will not only bring new knowledge, experience and information toward disaster risk reduction, but also helped build better coherence of DRR with the mainstream agenda of UN today toward inclusive, resilient and sustainable human societies.

Team of IRDR-IPO

Sustainable Infrastructure Development, Risk Perception and Vulnerability Assessment in Indian Himalayan Region

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Content

Abstract of this Working Paper

Infrastructure development is an essential component of the growth in developing economies, particularly in the hill areas. Because of inaccessibility and harsh climatic conditions, the hill areas in India offer limited livelihood options, and the level of economic activity is low. Inadequate transportation and communication links of these regions are strained often at times of heavy rains, snowfall, landslides, floods, etc.

The Himalaya represents tectonically alive, densely populated, and one of the most marginalized mountain regions of the world; it has experienced rapid urban growth during the last few decades. Fast construction activities are becoming increasingly common. This is threatening the fragile ecosystem of hilly areas, causing widespread soil erosion, aquifer damage, disturbing natural drainage and stream network, fault displacement and siltation of streams.

The risk-prone construction in hilly terrains is not only damaging the socioeconomic infrastructure for lives and livelihoods, but also the ambitions of sustainable development and resilient infrastructure. The green resilient highways, with ecosystem-based physical planning, executed with high standards of engineering using smart and environment-friendly materials and technologies, are appropriate options. Strategic networking with natural components for slope protection and stormwater drainage, and eco-link bridge for wild animals, insects, vegetation and water, etc. are some salient feature of ecosystem-based Blue-Green Infrastructure (BGI).

This Paper attempts to explore the acceptance of alternative ideas of green resilient highways from the context of community risk perception. The research team analyze vulnerability due to unsustainable infrastructure development in the Rudraprayag district, Uttarakhand, India. A multi-hazard profile, with a special focus on geo- hydro-meteorological disaster, is developed to analyze the vulnerability of the area towards the natural hazard. A detailed field and community-based survey are conducted to qualitatively establish a relationship between new infrastructure development (road construction) and associated risk. The Paper concludes on the optimistic note on the inclusion of BGI for such hilly terrains.

Indications of contributions to IRDR Science Plan and UN Agendas

IRDR Sub-objectives	3.1
SFDRR targets	SFDRR Target B and D
SDGs and/or Climate Goals	SDG Target 1.5, 6.6, 9, 11, 13
S/T Roadmap actions	

1. How does this study contribute to IRDR research objectives?

Most development activities, especially the construction of infrastructure, is happening at the cost of the environment. We do not yet fully understand the relationship between development and associated disaster risk, especially in the long run. Therefore, this Paper works in principle with IRDR objective (3): Reducing risks and curbing losses through knowledge-based actions, and objective (3.1): Vulnerability Assessments. The framework presented here supports a hypothesis that unscientific development at the cost of environment adds to the vulnerability of the region. The Paper attempts to highlight the importance of sustainable development.

2. How does this study contribute to SFDRR targets?

The study primarily contributes to target (b): Substantially reduce the number of affected people globally by 2030, by encouraging sustainable development; also the target (d): substantially reduce the disaster damage to critical infrastructure and developing resilience by 2030. Besides the study contributes to multiple Sendai Framework targets, by trying to establish the relationship between the infrastructure construction activities, unsustainable development and long term associated risks. No-new risk motto is at the centre of the study. We see the potential for developmental activities in sync with the nature for transforming development that consider a broader range of risks, as well as the connections with sustainable development and climate change. Ecosystem-based DRR is the linkage between SFDRR, SDGs and Climate Goals. And the study here explores the opportunity of implementation of the blue-green infrastructure (BGI) in multi-hazard prone areas with fragile ecosystems.

3. How does this study contribute to SDGs and the Climate Goal?

The framework discussed here has direct relevance to SDG targets 1.5, 6.6, 9, 11, 13, and 15. Target 1.5 is to build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters by 2030. Target 6.6 is to protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes by 2020. Substantial increase in the share of renewable energy in the global energy mix by 2030 is deliverable of the Target 7.2. Target 9 has set objective to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Inclusive, safe, resilient and sustainable cities and human settlements are objectives delineated in Target 11. Target 13 is to take urgent action to combat climate change and its impacts. Target 15 is to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. This study can contribute to pursuing DRR, sustainable development and climate change policy goals in greater harmony than is done so at present in most contexts.

4. How does this study contribute to Science & Technology Roadmap Actions?

This study supports the S&T expected outcome of a stronger involvement and use of Science to inform Policy- and decision-making within and across all sectors at all levels. Specifically, we hope the framework and approaches discussed here can facilitate significant dialogue between scientists/ researchers and decision-/policy-makers in both the DRR and sustainable development spaces, around the need to transform the relationship between development and disaster risk towards more equitable, resilient and sustainable outcomes for all.

5. Main recommendations to DRR policy if not yet highlighted in the main texts?

The overarching recommendation of this study to DRR, scientific community and development decision-makers is to better account for the sustainability of the infrastructure construction, and the complex relationship between development and disaster risk. The recommendations made in the study shall be integrated in the CDRI policy to develop infrastructure in a multi-hazard ecosystem. Further, we encourage stakeholders to prioritize interests based on the development-disaster risk trade-offs, with the highest priority to sustainable development. The Center of Excellence in Disaster Mitigation and Management (CoEDMM), Indian Institute of Technology Roorkee (IITR) stands ready to support any actors wishing to pursue research collaborations towards Disaster Risk Reduction and Sustainable Development.

Preface

The Himalaya region is highly sensitive because of continuous mountain-building activity as well as seismic susceptibility. Various developmental activities, such as road construction, mining and hydropower projects are often considered devastating to the local environment and ecosystems, which have raised diverse issues and challenges for the well-being and progress of the region. Therefore, it is strongly desired to address sustainable development issues and challenges across all ecosystems and landscapes of the Himalaya.

This Working Paper is the result of desktop research of the regional development challenges, survey (physical and questionnaire) of a selected vulnerable stretch which is identified for significant infrastructure project development, yet has a multi-risk history. The search for the answer to "how are the ongoing development activities (road construction) affect the vulnerability profile of a region at a local level" is the key motivator of this report. Analysis of the scenario is extended to a logical conclusion, thus by providing recommendations.

The Paper is an effort to contribute to IRDR's continuous initiative to bring focus on the burning issues related to disaster risk. We are thankful to Dr Qunli Han, Executive Director – IRDR, who provided us with continuous support to complete the report. We appreciate the effort put together by Ms Fang Lian in designing and editing the same. The help extended by the Indian Institute of Technology Roorkee to conduct the study successfully is humbly acknowledged. Wish the report will lit many sound minds and we can get a balanced development approach for the fragile Himalayan region in future.

Main Text

1. Background

Hilly terrains are inaccessible due to poorly developed infrastructure in developing economies. It is expensive to lay roads and rail lines in the risk-prone hilly terrains. However, road infrastructure construction is driven by targets of accessibility, balanced regional development, religious and eco-tourism, among others. However, due to insufficient sound engineering practices, infrastructure development is a major cause of increased vulnerability of the region. These factors have a direct effect on the productivity of land, groundwater resources and disaster risk resilience, which are crucial for the survival of populations in these areas.

The Himalayan ecosystems represent a complex and interrelated ecology of planet earth. It is one of the longest, loftiest and dynamic mountain chains on earth, spreading over a length of 2500 km covering six countries (Pakistan, India, China, Nepal, Bhutan and Bangladesh), and is a vast reservoir of resources – flora, fauna, water and fresh air. The Indian Himalayan region extends over an area of 594,427 km^2 (18.15% of India) covering ten states fully and two states partially. The region supports 6.36% of India's population (2011 census). It is also considered a regulator of the Indian monsoon and cold northern winds, and is categorized as the world's youngest mountain chain. The average forest cover of the area is 38%. Interestingly, the region contributes 63% to India's water budget with Brahmaputra basin contributing 34%, Ganga basin 25%, and Indus basin 4% to the total water.

The Himalaya region is inherently unstable, fragile and prone to natural disasters, even more, when inefficient rapid construction activities are destabilizing the region. The socioeconomic and cultural characteristics of local communities are closely linked to this dramatic ecological setting. The Himalaya, as a region, has always been susceptible to disaster, due to the neo-tectonic mountain-building process, like earthquakes, landslides, floods, etc. The spread of reckless developmental activities has amplified the disasters and thereby intensifying the damage. Such calamities play a grave negative socioeconomic role in the national economy and exert additional pressure on an already strained national economy. With the change in the climatic conditions worldwide, the hills in recent times have been witness to abnormally heavy precipitation and associated disaster.

To develop focused discussion on near-similar phenomena of risk-proneness among all the Indian Himalayan states and their development pattern, the reference of the state of Uttarakhand is contextualized in this Paper.

The Uttarakhand state, in the northern boundary of India, is popularly known as Devbhumi (land of Gods) due to the presence of numerous Hindu pilgrimage sites. As a result, religious tourism forms a major portion of the tourism in the state. Disruption of road connectivity causes immense hardships to the pilgrims and local public. In these situations, the state often has to resort to extraordinary measures for evacuating stranded people and for ensuring the availability of essential commodities and services. This puts a heavy burden upon public exchequer and hampers the pace of development. Special emphasis to be given to non-/structural measures, regulated tourism, better vehicles movement, enforcing zones, policies, rules, etc.

The extreme weather events are catastrophic as they bring with them a lot of water and mud. When this columns of water run down the mountains, washes away whatever comes in its way. In the year 1998, the Uttarakhand state witnessed major landslides at Malpa that took toll of more than 350 human lives (Paul et al. 2000; Rautela and Paul 2001). Building and houses are razed down; people and animals become a casualty of getting entrapped in the debris. In 2010, Uttarakhand experienced unusually high rainfall between 16 and 20 September that resulted in a number of landslides, cloudburst and flash flood events throughout the state (Sharma 2012). Then in 2012, particularly heavy rainfall was received between 4 and 6 August 2012 in Uttarkashi and 13 and 16 September in Rudraprayag. Around 236 villages and some towns, including Uttarkashi with a population of 13,137 were affected by these incidences (Rana et al. 2012). Similarly, in 2013 heavy precipitation in the region caused massive devastation in the state on 16 and 17 June 2013. More than 4000 persons went missing in these incidences that caused massive loss of infrastructure and property. More than 19,309 residential houses were damaged while around 11,091 farm animals were lost (Rautela 2013).

According to the terminology of UNDRR, vulnerability is defined as "the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards". Vulnerability is multi-dimensional in its nature, and next to the four dimensions above, some authors also include cultural and institutional factors. Examples include, but are not limited to; poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, high levels of poverty and education, limited official recognition of risks and preparedness measures, disregard for wise environmental management or weak institutions, and governance.

With this background, there is a need to examine the present situation of anthropogenic influence critically and hurried infrastructural construction status in the Himalaya. It is important first to understand the complexities and contradictions to have a holistic policy, and then change them according to the existing crises of the infrastructural vulnerability base in the Himalayan ecosystem. An ambitious highway construction project is initiated in the Uttarakhand state in 2016, called as the Char Dham Highway Development Project (*Char Dham Mahamarg Vikas Pariyojana*) to connect four Hindu shrines. The Char Dham highway development project and associated lane-widening have become debatable, with local residents, experts and environmentalists saying that it endangers the fragile mountain ecosystem. While constructing such a megaproject, all possible considerations are expected to be ~~properly~~ adequately accounted for, such as scientific, engineering, technological, environmental, climate, ecological and cultural ones.

The purpose of this study is to recognize the vulnerability of the Himalayan region due to Infrastructure development and its effect on geo-hydro-meteorological hazard. In this study, we offer a broad field and community survey to establish a relation between infrastructural necessity, construction activities, new hazards and the effect on the lives of the people of the region. The relevance of ecosystem-based blue-green infrastructure (BGI) and green resilient highway will be commented upon. A unique area-specific study is preferred over the prevalent general studies.

2. Study Area: Survey Location and Geographical Environment

The Char Dham Highway Development Project is proposed to be all-weather two-lanes in each side. Road widening along the existing route will include tunnels, bridges, way-side amenities like parking, helipads and emergency facilities. The selected survey location is on the National Highway (NH) 107, the part of the Project, and passes through the highly rugged terrain of the Mandakini valley in Rudraprayag district of Uttarakhand, Mandakini valley houses many pilgrim and tourist destinations that include the internationally known Shri Kedarnath Temple. The area is therefore visited by a large number of people every year, especially during the pilgrimage season that coincides with the monsoon period, the rainy season in the Indian subcontinent. The economy of the region besides agriculture, forests revolves around tourism and pilgrimage; disruption of the tourist or pilgrim traffic from frequent landslides, cloudbursts and floods, especially during the monsoon season has a major adverse impact on the economy.

The unstable nature of the area is further surcharged through various infrastructure development projects. During the last decade, extensive expansion of roads (Chardham Highway project) and settlements have taken place in this catchment. Sometimes, not guided by the geology of the area, roads have been constructed, and triggered several landslides. Rockfall along the roadside is also a common feature. Further, climate change also adds to the problem through glacial melting, creating glacial lakes and increased cloud burst incidents, etc., Therefore, besides the current vulnerability of the region, there is a lot more new risk building in the Himalayan state.

While multiple issues exist in the state together, the problem statement for this particular research has been simplified by analyzing the road infrastructure development and associated problems. For tourism, rapid construction of a 4-lane highway along the district of Rudraprayag is being carried out extensively. The NH107 is one such road connecting Rudraprayag to Gaurikhand has been selected for the study. A total of 5 towns, namely Silli, Vijya Nagar, Ganga Nagar, Kund and Chandrapuri of Rudraprayag district are surveyed for the in-depth interviews in this study (Figure 1). The justification for the particular stretch is further explained with the help of Figure 2 describing the disaster profile (notably the earthquake, landslides and cloudburst) of the area.

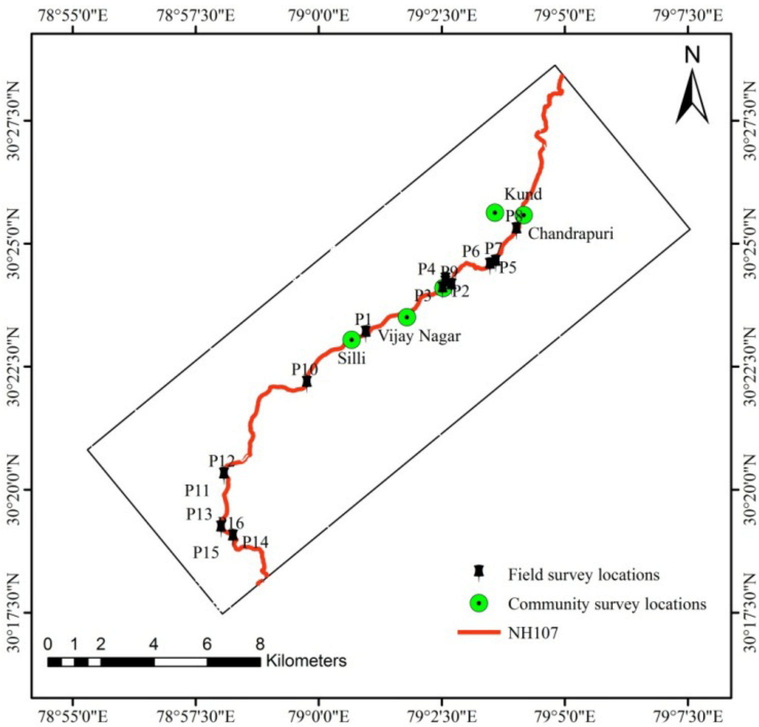


Fig. 1: Study area along with field and community-based survey location map

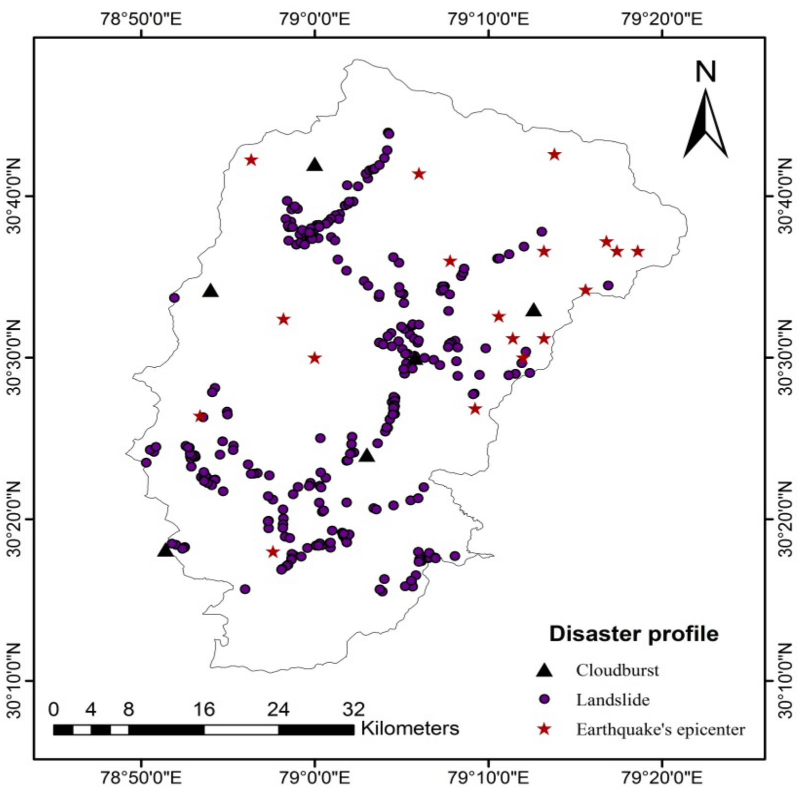


Fig. 2: Disaster profile of the Rudraprayag district

3. Conceptual Framework

The conceptual framework of this study consists of three phases, namely, problem definition, create a hypothesis and test the hypothesis. The framework responds to the three priority areas of Action out of four, as identified in the Sendai Framework for Disaster Risk Reduction (SFDRR, 2015). The working methodology involves in the Paper: (i) Understanding the area through extensive literature review (ii) Understanding the increasing hazards and risk due to unsustainable infrastructure constructions (iii) Mapping of the region through geographic information system (GIS) to understand the frequency and vulnerability of the region to hydro metrological hazard (iv) Field survey to investigate the road construction-related issues (v) Community-based survey to understand issues specific to the region and understand the perspective of the locals and impact of development on the community.

The first step of this study is to define a problem. An extensive review of the available literature, including previous researches, journals, and other published materials, was done to collect relevant information for enhancing understanding of critical issues. Apart from this remote sensing data and GIS application are used to frame a multi-hazard profile. Based on desktop research, the identified problem statement is "how are the ongoing development activities (road construction) affect the vulnerability profile of a region at a local level". Based on the hypothesis, a critical location has been identified. With the help of Google Earth image and Handset GPS, locations of field survey points were confirmed, and the same was marked (refer Figure 1). The experiences of various sections of local communities are captured through a detailed survey. Attempts were also made to apply the proposed hypothesis to the study area, test the hypothesis, further propose useful recommendations. Flowchart of the working methodology is given in Figure 3.

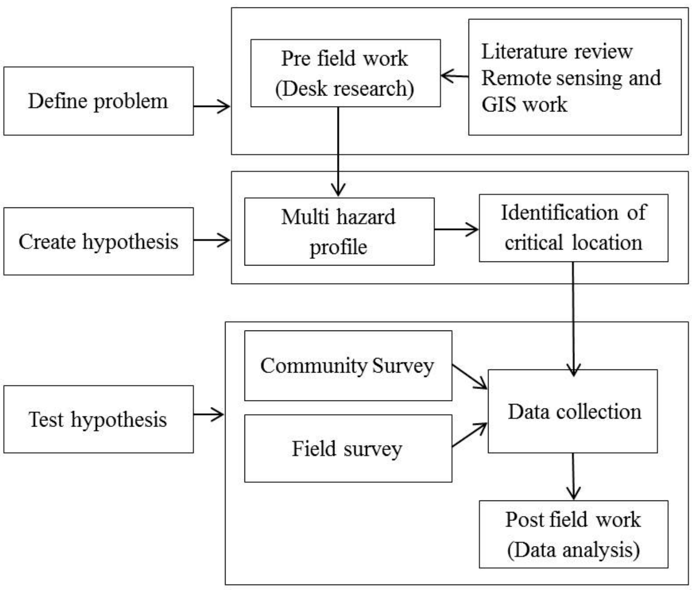


Fig. 3: Conceptual framework of the study

4. Effect of Infrastructure development on Vulnerability of the Study Area

4.1 Demography and Development

Uttarakhand is now known as the 'energy state' of India due to the existence of more than 200 large and medium-sized hydro-projects commissioned, and several projects being built on its major and minor rivers. This requires stream diversion, large-scale excavation of rock by blasting, tunnelling and dumping loose rock debris/soil, creating unstable land-forms prone to slope instability. The large size hydro-projects are to be blamed for the environmental menace, and almost all the rivers are being dammed to use the valuable water resource for electricity generation without taking into account the future consequences of restricting environmental flow. However, as the developmental activities in the state have not been operationalized and conducted in an unsustainable manner; therefore, the pitfalls of such developmental activities are being felt everywhere (Maikhuri et al. 2017).

Rudraprayag's population in 2001 census was 227,439, and 242,285 in 2011. There was an increase of 6.53% in the population during the 2001 to 2011 period (Census 2011). The constant increase in the infrastructure development of hill slopes in the Himalayan region with high population densities causes mountain ecosystems to undergo extensive changes in land use, i.e. increase in the built-up area, household unit density, and the population. The replacement of forests by agriculture and settlements is thought to cause severe erosion and landslides (Glade, 2003).

During recent years, development activities like the widening of roads, construction of tunnels, bridges, and dams have emerged as one of the important drivers of global environmental change transforming mountain regions. The extensive infrastructure development in fragile mountains has disturbed the critical ecosystem services. The unsystematic, unplanned and unregulated infrastructure has increased the slope instability, perturbed the hydrological regimes of Himalayan watersheds, reduced groundwater recharge and increased risks of natural hazards and disasters. On the other hand, the sustainable development of green, resilient highway projects in the high mountain can serve the centres of growth by creating opportunities of livelihoods, offering a variety of ecosystem- and socioeconomic services and contributing towards the development.

4.2 Effect of infrastructure development on geo- and hydro-meteorological hazard

Casualties and damage in recent disasters in Uttarakhand regions have increased due to climatic, geological, anthropological growth factors. The demand-based developmental activities without sound engineering and technological inputs are causing an imbalance in the natural ecology, and the environment is becoming more susceptible to natural disasters. The climatologist and environmentalist are in the opinion that the frequency and intensity of geo-hydro-meteorological disaster in Uttarakhand are increasing from last 30-40 years. These catastrophic events have brought the heavy toll to the human population, resources and the state infrastructure in terms of economy and societal.

The anticipated increase in precipitation, the melting of glaciers and expanding seas have the power to influence the Indian climate, with an incidence of floods, drought, flash floods, storms, cloud burst (Eriksson et al. 2009).

4.3 Landslide

Landslides account for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands in India. In India, about 0.42 Million km^2 areas of the landmass (12.6%) are landslide-prone. As per BHUVAN portal, Government of India also gives special emphasis for the preparation of landslide hazard zonation (LHZ) maps, for the safety of pilgrims in important pilgrimage routes of India (Chawla et al. 2019).

For widening of the roads, precarious mountain slopes are being cut haphazardly with the use of heavy machines like diggers (backhoes), excavators, tractors, and diesel engines. The process has removed the vegetation cover on slopes downhill and exposed underneath soil and rocks to water and erosion along the slopes. There have been many reports showing how hasty widening of roads has destabilized the slopes and induced multiple landslides. Casualties due to landslides in 2019 are reported by district disaster management authority (DDMA), Rudraprayag (https://rudraprayag.gov.in/disaster-managment) as presented in Table 1. The report shows that more than ten people died and 30 people were injured due to the landslides along NH 107.

Figure 4(a) shows the landslides marked on the local map. Through Field observation and reported from various literature, landslides are classified based on the type of material, movement and hydrological condition. Details are presented in Figure 5. In total, 51 landslides have been observed (Figure 2). Of these, 16 numbers are debris flow, 27 numbers rockfall and 8 numbers debris cum rock. Analysis of data pertaining to the landslide observed in the field shows that the majority (53%) falls in the category of rock material (Figure 5).

Table 1 Casualties reported by DDMA Rudraprayag

Date	Location	Causalities
21/10/2019	NH 107 Chandikadhar	8 dead
13/06/2019	Banswara	3 dead and 12 injured
12/07/2019	Chhoti Lincholi	16 injured
10/06/2019	Near Ukhimath	5 Injured
11/05/2019	Near Lincholi	1 dead

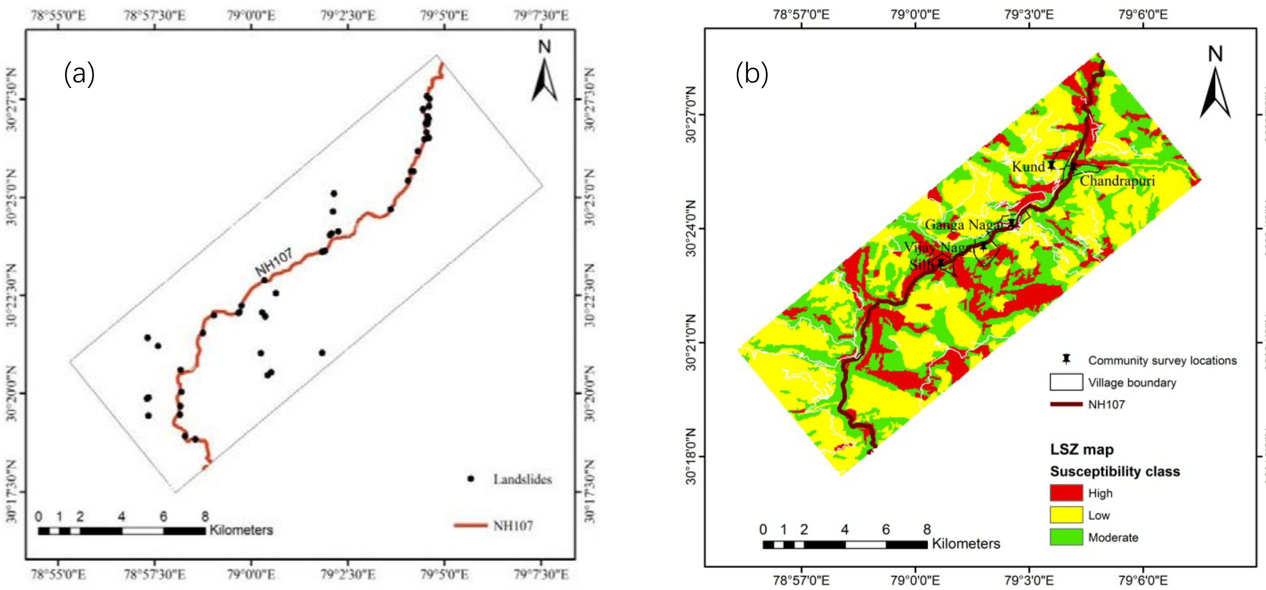


Fig. 4 (a) Landslide inventory map reported; (b) LSZ map (Source: GSI)

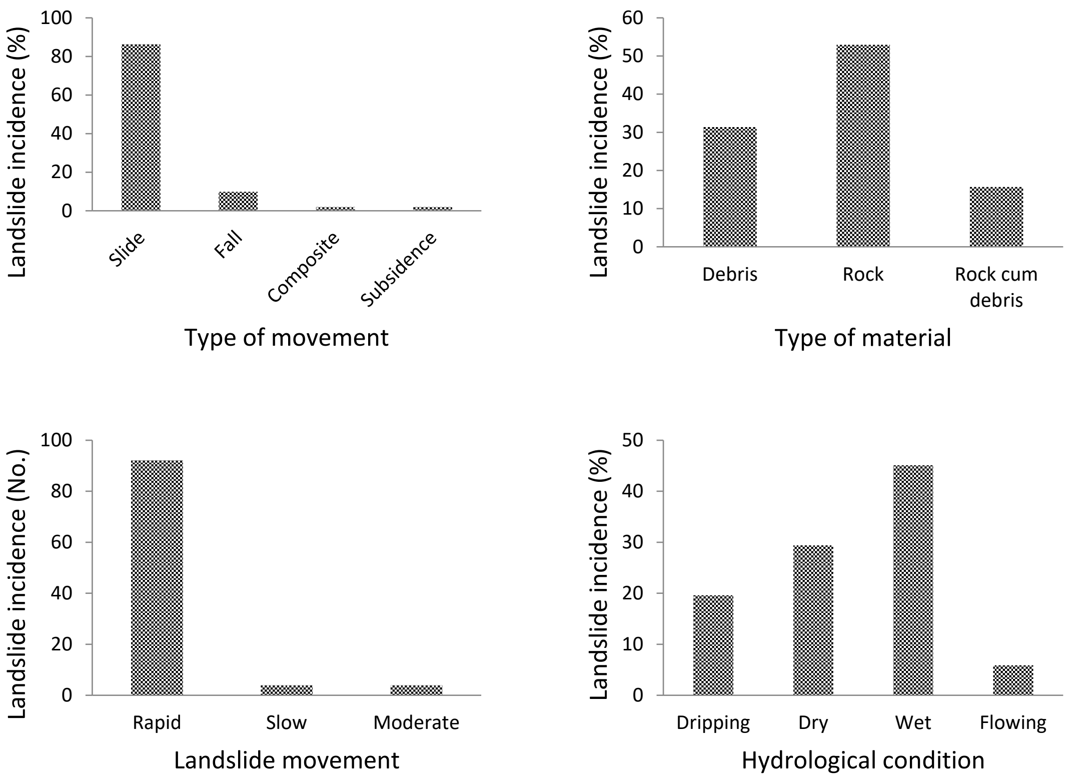


Fig. 5: Classified landslide events based on material, movement and hydrological condition

The survey area is dominated by the slide-type of movement, which covers 86% of total landslides. This makes it amply clear that the overburden or debris material was saturated by prolonged heavy rainfall, and the same was responsible for the initiation of landslides. Field observations suggest that the landslides in the study area are largely concentrated in close proximity of the road and stream networks. Change in slope geometry for road construction and toe erosion by the stream are the reasons thereof. The relationship of these two parameters on the distribution of landslides is therefore accorded special attention.

Landslide susceptibility zonation (LSZ) map (Figure 4b) shows that most of the area of Silli, Kund and Vijay Nagar is falling in very susceptible class while Ganga Nagar and Chandrapuri is lying into moderate and low susceptible class. Along with the NH 107, most of the area is prone to landslide and falling into moderate and high susceptible class.

4.4 Cloudburst

A devastating impact of climate change can already be seen with disastrous cloudbursts and floods taking place with increasing frequency in the Himalayan region. This is being exacerbated by the unscientific methods of dam and road construction, which led to many landslides blocking highways and affecting local communities.

The high-intensity rainfall of more than 100 mm/hour in a few square kilometre areas is generally defined as cloudburst (Das et al. 2006). In recent years, anthropogenic factors such as population, deforestation, land-use change and emissions due to infrastructure development have been implicated in extreme weather events in the Himalayas. Table 2 shows the major cloudburst events in Rudraprayag district.

Table 2 Details of cloudburst events reported in the Rudraprayag district, Uttarakhand, India

S. No.	Date and time	Location	Damage	Reference
1	17/08/1979	Kuntha	39 humans, 39 animals, 20 houses	Joshi and Kumar (2006)
2	17/08/1979	Sirwari	13 humans, 150 animals, 34 houses	Joshi and Kumar (2006)
3	11-19/08/1998	Okhimath	103 humans, 422 animals, 820 houses	Joshi and Kumar (2006)
4	11/08/2001	Phata	27 humans, 64 animals, 22 houses	Joshi and Kumar (2006)
5	2005	Agastmuni & Vijaynagar	--	Asthana and Sah 2007; Sati et al. 2011
6	13/09/2012	Ukhimath	66 humans	Rana et al. (2012), Chevuturi et al. (2015)
7	16-17/06/2013	Kedarnath	6600 humans, 365 houses	Mishra and Srinivasan (2013), Asthana and Asthana (2014)

5. Risk Perception Mapping by Field Survey and Local Community Interview

Risk perception and vulnerability are complex and strongly interrelated notions. Rather than depending on expected values, risk perception is socially constructed and transmitted; and it is related to the socio-environmental context (Renn 1992), which influences individual decisions (Howden et al. 2007). At the same time, vulnerability is a theoretical concept, not directly observable, which depends on socioeconomic and institutional factors as well as on biophysical and environmental issues (Abid et al. 2016). Therefore, this Working Paper reviews the main insights on risk perception of communities, particularly in connection with natural hazards from community-based interviews and field-based surveys. It includes numerous interviews on the perception-based questionnaire and opinion on infrastructure development activities.

The study reveals that despite knowing the risk of disaster due to new infrastructure development activities in a highly sensitive area like Uttarakhand, most residents see this as an opportunity for a better future prospectus.

5.1 Community Interviews

Discussions and interviews with stakeholders were conducted in the predefined survey locations. A total of 120 people were interviewed. The interviews covered all the sections of the people like the district administration, district disaster management, district education officials, government schools, government hospitals, armed forces, tourists, local travel service providers, farmers, shop keepers, etc., Efforts were made to capture community's response along with field evidence.

For the in-depth interviews, focus groups related to the administrative authority, decision-makers, policymakers, and local community are selected; detail information is presented in Table 3. Approximately 3-5 people have been interviewed in each focus group.

Each Interviewee from the identified focused group was informed briefly about the purpose of the study. They participated in the semi-structured questionnaire-based discussion; this helped to gather their risk perception about the Char Dham Highway Project for the qualitative assessment. The questions were about the respondents' perception and thoughts on this infrastructure development project, speed and quality of construction, associated challenges and risk, and consideration of fragile Himalayan ecology. Extensive physical survey of the stretch identified is the other methodology adopted for this research study.

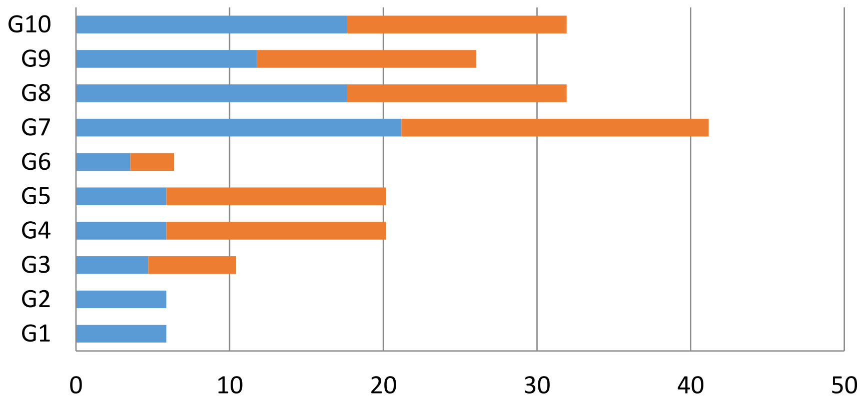
Table 3 Details of Focused Groups selected for Interview

Survey group	Survey group classification	No. of people interviewed (No.)
G1	District administration office	5
G2	District disaster management authority (DDMA)	5
G3	District education Officials	6
G4	Government schools	10
G5	Government hospitals	10
G6	Armed forces	4
G7	Tourists	25
G8	Local travel service providers	20
G9	Farmers	15
G10	Shop keepers	20

5.2 Analysis and discussion of the Survey

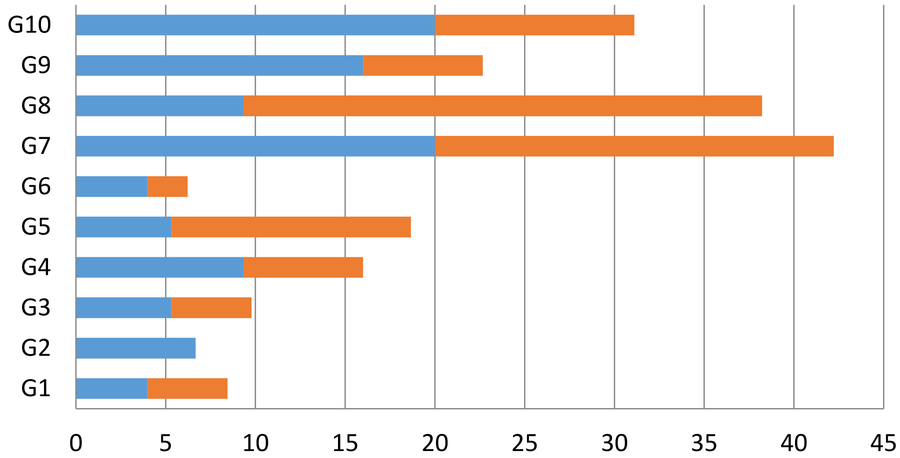
5.2.1 The road development project and speed of the construction

Survey analysis shows that 83 % of people are in favour of the widening of road projects, whereas 17% are against the project (Figure 6). Also, 65% of people were in complete agreement with the rapid speed of construction of the road and extended the support to the government (Figure 7).



	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Yes (%)	6	6	5	6	6	4	21	18	12	18
No (%)	0	0	6	14	14	3	20	14	14	14

Fig. 6: Statistics of responders concerning the highway Project Initiation



	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Yes (%)	4	7	5	9	5	4	20	9	16	20
No (%)	4	0	4	7	13	2	22	29	7	11

Fig.7: Statistics of responders regarding the speed of the construction

5.2.2 Awareness of community about associated risk with the Infrastructure Project

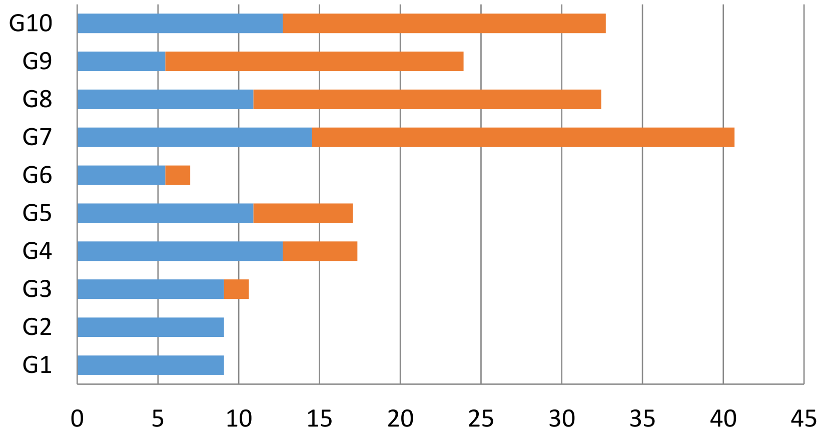
The questionnaire survey results have pointed out that a larger group (53%) are not much aware of the risks which can be induced due to new infrastructure development, as shown in Figure 8. Common people are in full support to the construction practices as they are looking forward to a better future and economic opportunities. In the 2000's, when the road widening project had started, the construction practices involved blasting and other dangerous practices, while the current method is much better than that existed in most of the segments. The community support this change.

The government officials are of the opinion that the slope will be stabilized over a period of 5 years to 10 years. This opinion can be critically reviewed in three aspects:

i) The stabilization period will depend upon the rock characteristics of the region. Different rocks tend to have different slope stability and will stabilize over a period accordingly. The slope stability also will depend upon several other aspects such as slope angle, climatic conditions, anthropogenic forces, etc.

ii) Secondly, a lot of damage will be caused to people and infrastructure due to landslides during this process of stabilization. Not to mention the inconvenience that would be caused due to roadblocks among other challenges.

iii) Thirdly, the cost of damage, maintenance and repairs will far exceed the cost of constructing a sustainable infrastructure.



	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Yes (%)	9	9	9	13	11	5	15	11	5	13
No (%)	0	0	2	5	6	2	26	22	18	20

Fig. 8: Statistics of responders about awareness of disasters associated with infrastructure development

5.3 Physical survey of construction practices for the contemporary highway project

The construction practices for highway infrastructure is based on sound engineering principles which in turn is communicated through detailed project reports(DPR).Mountain slope management is one of the most critical issues for consideration in highway development in the Himalya. A DPR ideally shall considers the multi-hazard ecosystem the infrastructure needs to withstand successfully. Community risk perception cannot accommodate enough the hazard perspective of the risk matrix; both vulnerability, coping capacity and exposure play overriding roles. This following section explores risk associated with contemporary construction practices for a specific highway widening project through field visit, and documents risk perception of local community and risk managers.

5.3.1 Steep slope cutting and neglecting the geological condition

When interviewing the construction workers, it was realized that a standard instruction is issued to them to execute cutting despite the difference in road width and geology. While the slope may get supported on certain kinds of geology, such as hard rock, the slope is undoubtedly dangerous for soft soils and fractured rocks.

Figure 9 shows the different type of rocks observed in the study area and the same steep slope cut. As per experts mountain's slopes should not be cut at 80° or 90° angle but at many places steep cutting has been observed. Along the 70 km road, from Devprayag to Rudraprayag, one can witness different types of geological compositions, like soft soils, hard rocks, fractured rocks, etc. Critically examining the construction practices, it was evident that road width was given more importance over the slope stability. The drainage and aquifer characteristics of the area were not considered during the construction.

Fig. 9: Geological condition of the study area: (a)River Borne Material (RBM) unconsolidated form; (b) Phyllites, Metamorphic rock; (c) Hard and jointed rock is overlain by RBM; and (d) Slate/foliated metamorphic rock

5.3.2 Detailed Project Report (DPR)

Robust DPR preparation requires high standards of multi-expert teams' involvement. The lowest bid system to choose for design, construction and maintenance are depriving us of safe and quality engineered infrastructure; we are also losing the surrounding ecological balance as these parameters are omitted rampantly to keep the cost low.

5.3.3 Non-availability of the site-engineer

According to the highway construction norms, an engineer has to be present at the worksite, in all the 12 work sites witnessed, engineers were nowhere to be seen. When discussing with the authorities, it was realized some construction norms are deliberately ignored to maintain the construction speed and low cost.

5.3.4 Traffic jam

The highway blockage cripples the daily life of the region as there is no alternative route where traffic can be diverted and hence, commuters can neither enter nor leave during the road blockage. Figure 10(a) is one such evidence of traffic jam during the field visit. These traffic jams are also polluting the environment with harmful emissions from queued cars. While the safety precautions taken by the construction personnel are much appreciated, it would be more convenient if the construction took place during night time, without obstructing the traffic, but with proper precautionary provisions such as lighting, safety norms in place and quality control.

5.3.5 Dumping of the material

At many sites, debris, rubble and muck generated during construction are being dumped directly into the river channels. This would definitely disturb the natural flow of the stream and rivers; they will cause a disaster like bursting of embankments and flash flood during monsoon. This could also disturb aquatic life and water quality of the stream. The excavated materials are supposed to be dumped in the identified dumping zones. Alarmingly, the identified dumping zones are also within the flood plains of the river. Figure 10 (b) depicts that most excavated material is being dumped into the river, saving transportation cost to the contractor.

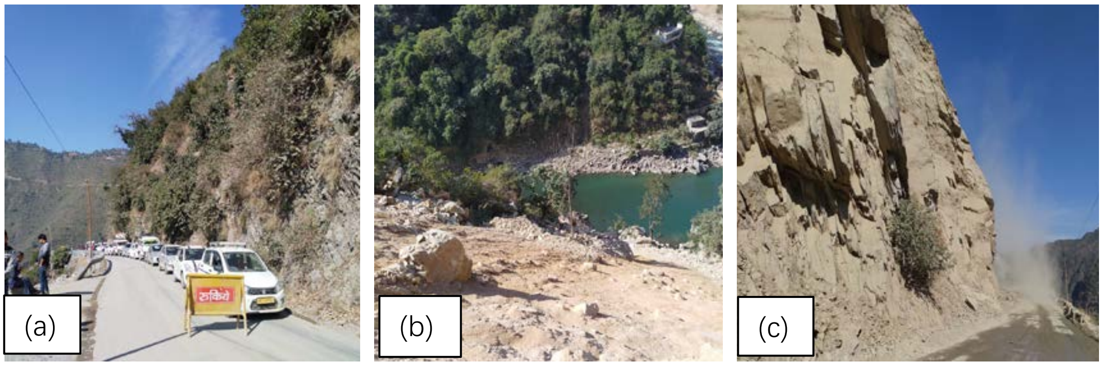


Fig. 10: (a) Traffic jam during the construction period (b) Dumping of Debris, rubble and muck dumped in the river & (c) Dust generated due to construction work

5.3.6 Dust

Dust is another major issue due to poor construction practices. Both design and construction technology aggravate the problem. Besides, a sprinkling of water to reduce the dust is poorly done within the towns. Areas far from towns are almost neglected. Dust causes severe respiratory and other problems to locals and commuters during the construction period, as shown in Figure 10(c).

5.3.7 Slope cutting through drilling

During the construction of the road during 1998-2002, large scale Improvised Explosives Devices (IEDs) were used. The large scale blasts led to the destruction of the hills massively along with the destruction of ecology and environment. The strong vibration caused by blasting is very likely to trigger landslides, avalanches, etc. The new practices of using the machinery to drill slope are pretty safe and sound on the young mountains.

5.3.8 Road accident

Vehicles falling into gorges are a regular problem in a hilly area, and narrow roads have often been the cause. So, the wider and smoother road will not only reduce road accidents but also save travel time. Shorter journeys will encourage people to open processing units and other industries in the hills, thereby giving rise to employment avenues.

5.3.9 Destroying aquifer

Because many of the streams are seasonal and small in size, the damage caused to the aquifers and small streams is being ignored. However, the locals expressed their disappointment regarding the aquifers being destroyed due to massive landslides and construction activities.

While the region does not have water security issues due to rich Himalayan rivers and dwindling population, there are few cases where the villages had to develop an alternative water supply system. This is due to the fact that small streams that supplied water to these villages for generations dried up eventually due to massive construction. While the current scenario is not very grim when critically analysed, the entire scenario indicates trouble to most parts of the Himalayan water system. The further effects of the rivers need to be analyzed in full.

5.3.10 Fragmented Ecology and Polluted Environment

The Char Dham Highway Project has a stringent demand on land to widen the roads. The Himalayan ecosystems are one of the most critical ecosystems, not only for India but also for the world. The creation of highways in hilly terrains is taking an irreversible toll on the biotic and abiotic ecosystem of the area (refer Figure 11). As no contingent planning and design for ecology and environment protection is being prepared, long term risks are being invited to brew. The local culture of the place is also not being reflected in this highway construction.

Ecosystem-based risk resilience is an emerging strategic policy for multi-hazard risk management. The Ministry of Road, Transportation and Highways of the government of India has launched the **Green Highways** (Plantation, Transplantation, Beautification & Maintenance) **Policy-2015** (MoRTH, 2015). Innovative application of the Policy will ensure continued ecosystem functions of the environment and risk resilience services. The BGI will create networked service by defragmentation techniques of natural elements of water and vegetation (Mukherjee and Takara, 2018). Both vegetated slope and drainage shall get priority in the BGI design. Figure 12 shows the terraced cutting for roads.

Fig. 11: Topsoil loss along the highway corridors

Fig. 12: Terraced slope stabilization with vegetated surface

Government of Uttarakhand is already engaged with several initiatives where nature-based mitigation is getting due priority, and NGOs and CBOs are committed to bringing pace in the implementation of BGI into reality. In districts of Pithoragar, Chamoli, Uttarkashi, Haridwar and Dehradun extensive awareness programme on nature-based solution is completed.

The road project discussed here is a cursor to present how the mountain ecology can be endangered with development projects in India, and beyond its boundary in Himalaya and in many other hilly regions of the globe. Nature-based BGI-networks shall be integrated as a remedial strategies as this brings benefits of safe and healthy environment to development.Multiple benefits-yielding interventions are now a mainstay of different Government projects across the region and the globe. And that is also a principle of nature-based solutions.Few such examples from other types of project are discussed below.

It has previously been recognized in the disaster and humanitarian field that the provision of relief materials and provision infrastructure shall go hand in hand with the promotion of healthy behaviours. Classic examples with hygiene promotion include the water and sanitation provision (WHO, 2013), and Swachh Bharat Abhiyan (Clean Indian Mission), a national level campaign by the Government of India (GoI) covering 4041 statutory towns to clean the streets, roads and infrastructure of the country (GoI, 2014).

The Ethnic Minority Health Project (EMHP)- Ma'an Qiao Village, in Sichuan province, China, has demonstrated the use of evidence-based interventions to build field-based bottom-up resilience for Health Emergency and Disaster Risk Management (Health-EDRM) at the community level (Chan et al. 2018). This also provides the basis for the communication of the disaster risks and the appropriate mitigation strategies. With the partnership of providing earthquake resistant critical infrastructure, the health interventions provided the knowledge and skills for villagers to reduce the mortality and morbidly from future disasters. A similar example can be found in India, where to achieve the goal of risk resilient infrastructure and growth of the rural and economically weaker population, the GoI implemented several subsidy-based housing schemes like Rajiv Awas Yojana (RAY) and Pradhan Mantri Awas Yojana (PMAY) over the past few decades. Resilient features, and innovative use of local and new materials are now necessary components in these programmes.

To reduce climate risks and enhancing resilience of vulnerable communities primarily through practical action, a global project Ecosystems Protecting Infrastructure and Communities (EPIC) has been launched by involving six countries (Nepal, Chile, Thailand, Senegal, China and Burkina Faso). The main purpose of the project is to catalyse and quantify the role of ecosystems in protecting vulnerable communities against the risks associated with climate change and natural hazards. In Nepal, the project falls within the specific context of rural earthen roads, exacerbating erosion and landslide risk in the Panchase area (Buyck, 2017). This project has helped reviving the eco-based livelihoods too.

These evidence-based examples highlight the importance and success of disaster risk reduction in communities for the SFDRR and the S/T roadmap.

6. Recommendations

India is an emerging economy; so, infrastructure development cannot be stopped or reduced in the Himalaya. Similarly, other countries who are going through massive development phases, are facing similar challenges. Definitely, they need to include more systematic, scientific and sustainable procedure. Rapid and unplanned infrastructure development is increasing the susceptibility of densely populated fragile slopes to the active processes of mass movement and landslides. Further, the rapidly changing climatic conditions, particularly the climate change-induced geo-hydrological extremes are posing severe threats to the sustainability of fast-growing urban ecosystem by increasing the frequency, intensity and severity of hazards in the towns and their vast hinterland.

Specific to the study area, the landslides have caused around 20 deaths in Rudraprayag district in the year 2019 alone. This highway, once completed, will definitely save lives with quick access to hospitals during critical times, will improve quality of life through easy access to education, jobs and other benefits. So, the more relevant question is, what shall be the best way forward, how the project can ingrain design, analysis, construction and maintenance without creating new risk for the area. The question remains, whether the vulnerability of the region is increased due to increasing hazards or is it reduced due to new infrastructure and access to hospitals, jobs and other basic socio-economic requirements. In view of this, the following recommendations are made:

1. While development is important for the hill region, the lack of appropriate approach suitable for the local conditions paints a dangerous picture for the present and future. While the region is already quite vulnerable, the new

infrastructural is adding to the vulnerability. The additional premium for environmental safety shall be integrated into the project cost.

2. A comprehensive assessment of multi-hazard and vulnerability of beyond identified stretches of construction area considering critical parameters of exposure, sensitivity and adaptive capacity of the local ecosystem is the pre-requisite.
3. A detailed and large-scale risk zone mapping at a regional scale shall be carried out analyzing the parameters of geology, structure, lithology, geomorphology, demography, economy and livelihood, infrastructure and services.
4. Increase in the frequency of landslides and hydrological disasters due to infrastructure projects in the Himalayan region shall be responded with robust multi-dimensional engineering solutions.
5. In places where infrastructure development cannot be avoided, aggressive pro-environmental mitigation activities should be carried with BGI, indigenous knowledge on slope stabilization and organic agriculture.
6. Non-structural measures such as streamlining the tourist inflow to the hills and incentivizing environmentally- friendly eco-livelihood activities are a way forward to sustainable development. Creation of green jobs shall get a priority.
7. Regional trans-boundary risk assessment shall be started at earliest.

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