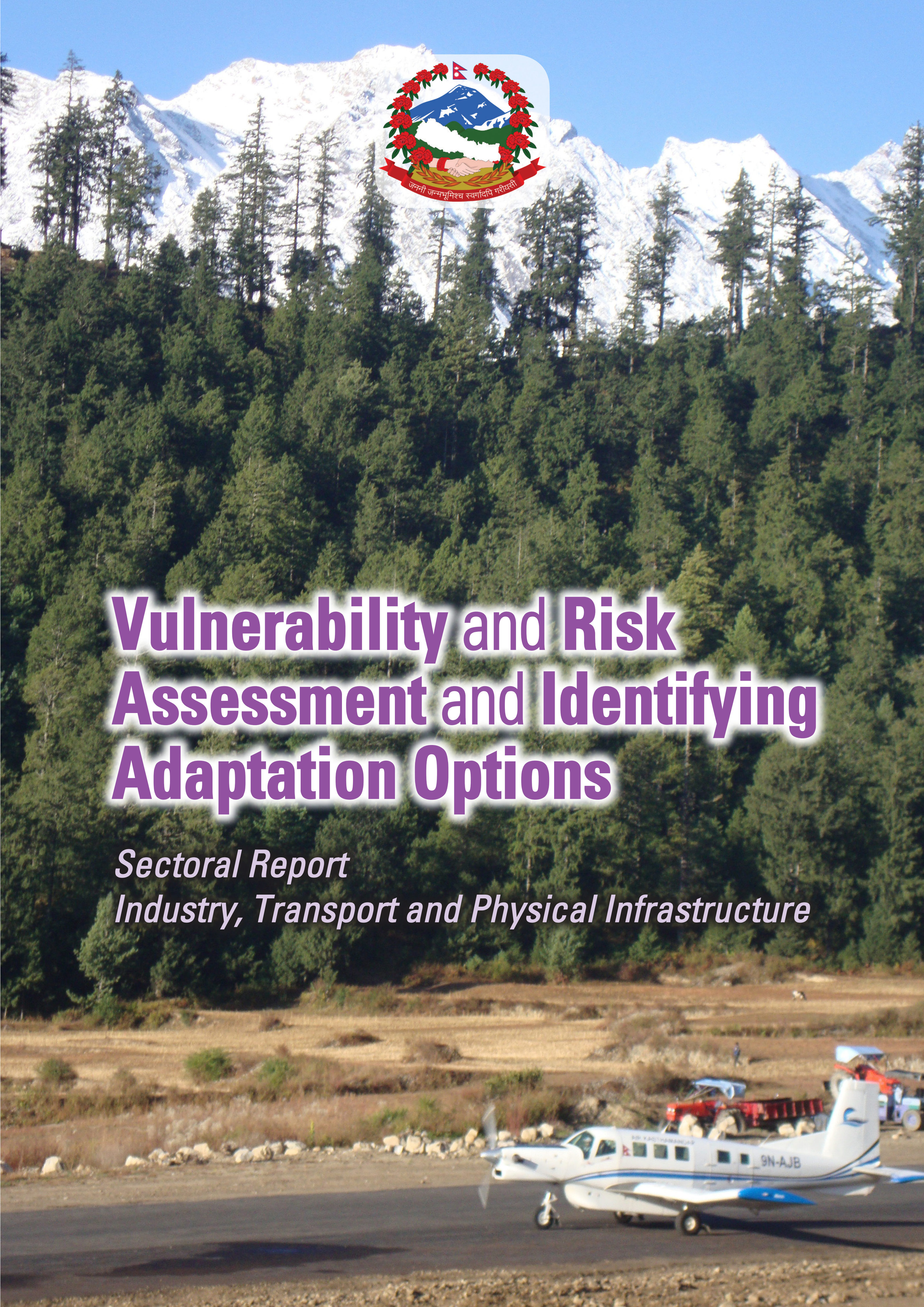

Vulnerability and Risk Assessment and Identifying Adaptation Options

Sectoral Report
Industry, Transport and Physical Infrastructure

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Foreword

Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. The latest IPCC report confirms that human activities have changed our climate and led to the more frequent heatwaves, floods, droughts, and wildfires that we have seen recently. The evidence is incontrovertible. This highly influential report provides the evidence base and impetus to develop policy strategies and practices that will help people around the world and in Nepal live with and adapt to change.

Nepal has been a pioneer in the development and implementation of effective adaptation policies and practices. Nepal has made a strong commitment to updating a mid-long term National Adaptation Plan (NAP) every ten years, as well as conducting a National level Vulnerability and Risk Assessment every five years to inform climate resource allocation policies. Vulnerability and Risk Assessment (VRA) was initiated to assess vulnerability and risk at the national, physiographic, province, municipal, and sector levels to inform the Government of Nepal's current NAP formulation process.

I am pleased to see that the VRA report on Industry, Transport, and Physical Infrastructure sector was prepared by identifying sector-specific current vulnerability and future risk based on a solid scientific foundation and information. This report is the result of a thorough consultation process with national and provincial stakeholders and experts. This report, I believe, provides an opportunity for policymakers, decision-makers, and practitioners to make informed decisions about sector-specific vulnerability and risk to build a climate-resilient society and reduce the impacts of climate change at the local, provincial, and federal levels.

On behalf of the Ministry of Forests and Environment, I would like to thank the distinguished Chair - the Joint Secretary of the Ministry of Physical Infrastructure and Transport , and all the respected thematic group members who provided technical guidance to finalize this report. In addition, I gratefully acknowledge the assistance provided by the Climate Change Management Division, particularly Dr Radha Wagle and all technical committee members.

I also take this opportunity to acknowledge the funding and technical support of the British Embassy Kathmandu, and Policy and Institutions Facility (PIF) /Oxford Policy Management Limited.

Dr Pem Narayan Kandel
Secretary
Ministry of Forests and Environment (MoFE)

Acknowledgments

The National Climate Change Policy (2019) identifies eight thematic areas and four cross-cutting areas which will be impacted by climate change. As such, there is a pressing need to understand how public and private investments might be impacted. Without adequate information on risks and vulnerability, it will be difficult to translate policy into action. To plan and implement a successful adaptation strategy, it is vital to understand the likely impacts of climate change on different sectors and communities, and, in particular, how these may evolve in the future.

A National Adaptation Plan (NAP) needs to be developed based on a strong scientific foundation and reliable evidence. This includes data and information about how the climate has evolved in the recent past and how it may further change in the future. To realise this, the MoFE has carried out detailed Vulnerability and Risk Assessments (VRAs) of the thematic areas identified by the National Climate Change Policy at the municipal, district, and regional scales. The VRA framework and methodology presented in the report are based on the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) and the NAP technical guidelines of the UNFCCC.

This VRA report contributes to the establishment of a strong baseline for climate change impacts, risks, and vulnerabilities in Nepal. In particular, it presents relevant information on social and structural vulnerabilities and risks triggered by the interaction of climate change and socio-economic, governance, political and cultural norms and practices. The report also offers a range of adaptation options for reducing root causes of vulnerability and risk, including enhancing social inclusion and reducing gender disparity.

On behalf of the Climate Change Management Division (CCMD), I would like to extend my appreciation to the chair, vice-chair, member secretary, and all the members of the Thematic Working Groups (TWGs) on Industry, Transport, and Physical Infrastructure sector for providing guidance and input in the VRA process. Also, I acknowledge the input provided by federal, provincial, and local governments, national and international organizations, community-based organizations, and communities.

Special thank goes to the technical committee members Raju Sapkota, Dr Arun Prakash Bhatta, Srijana Shrestha, Hari Pandey, Dr Indira Kandel, Gyanendra Karki, and Dr Bimal Raj Regmi who supported and facilitated the VRA process. We would also like to thank Rajan Thapa, Apar Paudyal, Dr Ram Prasad Lamsal, Dr Pashupati Nepal, Dr Bhogendra Mishra, Regan Sapkota, Basana Sapkota, Dr Nilhari Neupane, Dr Shiba Banskota, Pratik Ghimire, Rojy Joshi, Bamshi Acharya, Goma Pandey, and Prashamsa Thapa, from the PIF, who provided technical insights and were involved in producing this report.

Besides, I also take this opportunity to acknowledge the funding and technical support of the British Embassy Kathmandu, and Policy and Institutions Facility (PIF) /Oxford Policy Management Limited.

Dr Radha Wagle
Joint Secretary
Climate Change Management Division
Ministry of Forests and Environment (MoFE)

List of Acronyms

AC	Adaptive Capacity
AR	Assessment Report
ATC	Air Traffic Control
CANN	Civil Aviation Authority of Nepal
CAPA	Corrective and Preventive Actions
CBS	Central Bureau of Statistics
CCA	Climate Change Adaptation
CIA	Central Intelligence Agency
CIJ	Center for Investigative Journalism
DCSI	Department of Cottage and Small Industries
DHM	Department of Hydrology and Meteorology
DoI	Department of Industry
DoLI	Department of Local Infrastructure
DoLIDAR	Department of Local Infrastructure and Agricultural Road
DoR	Department of Road
DoTM	Department of Transport Management
EPA	Environment Protection Act
EWS	Early Warning System
FNCCI	Federation of Nepal Chamber of Commerce and Industry
FY	Fiscal Year
GDP	Gross Domestic Product
GHGs	Green House Gases
GIZ	German Agency for International Cooperation
GoN	Government of Nepal
$GtCO_2eq$	Giga Ton of Carbon Dioxide Equivalent
IBN	Investment Board Nepal
ICIMOD	International Centre for Integrated Mountain Development
IDS	Intrusion Detection System
IPCC	Intergovernmental Panel on Climate Change
ITPI	Industry, Transport and Physical Infrastructure

ILO	International Labour Organization
LDCs	Least Developed Countries
LRN	Local Road Network
MoCTAC	Ministry of Culture, Tourism and Civil Aviation
MoFE	Ministry of Forests and Environment
MoHA	Ministry of Home Affairs
MoICS	Ministry of Industry Commerce and Supplies
MoPIT	Ministry of Physical Infrastructure and Transport
MoPE	Ministry of Population and Environment
MoSTE	Ministry of Science Technology and Environment
NAP	National Adaptation Plan
NAPA	National Adaptation Program of Action
NCCP	National Climate Change Policy
NIB	Nepal Insurance Board
NIDC	National Industrial Development Cooperation
NPC	National Planning Commission
NRC	National Research Council
NRs	Nepali Rupees
NSTS	National Sustainable Transport Strategy
OECD	Organization for Economic Co-operation and Development
OPM	Oxford Policy Management
PIF	Policy and Institutional Facilities
RCP	Representative Concentration Pathway
RECP	Resource Efficient and Cleaner Production
SE	Sensitivity and Exposure
SRN	Strategic Road Network
TWG	Thematic Working Group
UNCRD	United Nations Centre for Regional Development
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
VRA	Vulnerability and Risk Assessment
WB	World Bank

Executive Summary

Industry, Transport, and Physical Infrastructure (ITPI) are key sectors that contribute to Nepal's economic growth, its future development, and the mobility of its people. The industrial sector contributes to 13.45 percent of the country's Gross Domestic Product (GDP) and provides 13.15% of total employment as of 2018, of which about 90 percent comes from the cottage and small industries. Similarly, the transport industry alone provides direct employment to nearly 20,000 people and 10.6 percent of the contribution to real GDP.

At the same time, the ITPI contributes to greenhouse gas (GHG) emissions in Nepal. Industries related to brick, cement, and metal, other manufacturing industries, and the food and beverage industries are the major contributors of emissions. Manufacturing industries emit 2,248 Gg of $CO_{2\text{-eq}}$. and is the largest contributor of CO_2 (48%) within the energy sector and the second-largest contributor of total GHG (17%) emitted countrywide. Based on Nepal's GHG inventory, emissions (CO_{2eq} in Gg) from fossil fuel combustion in the transport and industry sectors contribute to 13% and 17% of total emissions respectively. Within the transport sector, the main sources of GHG emissions are heavy vehicles such as trucks, tankers, and lorries, followed by light-duty vehicles such as cars, jeeps, and vans.

Given the above, it is clear that the economic prosperity of the country depends on the development, expansion, and promotion of its ITPI. However, this comes with costs. Major challenges exist concerning the functioning and sustainability of the industrial sector and road construction. These challenges can trigger and exacerbate the impacts from climate extreme events such as heavy rainfall, massive landslides, and floods. They include the haphazard building of roads without cognizance of risks. The geography of the country itself also plays a prominent role in its susceptibility to natural disasters. Therefore, the current practice of building poorly designed road infrastructure and excavator-led design increases the landslide-proneness of several areas. The prevailing cut-and-throw approach has altered the landscape, negatively impacting drainage, slope stability, erosion, and downstream sediment supply.

In addition to all other challenges, an increase in the average temperature and rainfall levels has a substantial impact on the planning and operation of roads. The Nepal Sustainable Transport Strategy (NSTS) 2015 examined the impact of climate change on the transport and (transport-related) physical infrastructure sectors and found that the transport infrastructure constructed over the last six decades is more susceptible to rapid changes in climate because of its traditional design and implementation methods. Poor road conditions correlate to high transaction costs and economic loss. As a result, the expansion of economic opportunities becomes confined. Therefore, this study, a Vulnerability and Risk Assessment (VRA) of Nepal's ITPI, is crucial for understanding current vulnerabilities and risks within these sectors, and for identifying relevant adaptation options and mitigation targets. It is hoped that this report will ultimately improve the preparedness of these sectors to deal with the potential future risks.

The overarching objective of this study was to assist the formulation of Nepal's National Adaptation Plan (NAP) by conducting an assessment of current and projected impacts of climate change on the country's ITPI and associated vulnerabilities and risks so that sector-specific adaptation policies and plans can be identified and formulated. Specific objectives included: (i) assessing risks and vulnerability to climate impacts across the industry, transport, and infrastructure sectors and physiographic regions through applicable frameworks; and ranking/categorizing associated climate risks and vulnerabilities; and (ii) identifying adaptation options, at multiple scales (district, province and physiographic regions), to address priority risks and vulnerabilities.

For this VRA, a mix of top-down and bottom-up approaches was used. The top-down approach involved long term national and regional climate change modeling, impact projections, and adaptation strategies, identified through technocratic cost-benefit analyses. In contrast, the bottom-up approach involved a consultative process designed to empower local and provincial government and stakeholders, including communities, by encouraging self-assessment of climate impacts methods. This approach is useful in checking and validating information derived from top-down approaches. The framework and the nine-step methodology were based on suggestions included in the IPCC AR-5 and the formulation process of the NAP.

The physical transport infrastructures in Nepal are impacted by floods, mass wasting, debris flow, sedimentation, rise in groundwater levels, rain, and windstorms. Common problems include the collapse of industrial buildings and properties; increased exhaustion of infrastructures; silting of drains; increased instability of land through the weakening of riverbanks, hill toes or land subsidence; inundation; and submergence of infrastructures. Related impacts consist of high costs for maintenance and repair; limited community access to jobs, schools, and hospitals; and large economic losses.

In many cases, the impact of climate change in the industrial sector has created more stress on employment generation and created disturbances in the supply chains. The ITPI sectors have also inherited problems such as unsustainable industrial planning and poor transport infrastructure. Other challenges include lack of safety and compliance during the construction of new roads and maintenance of old existing roads and industries; the likelihood of natural disasters; and vulnerabilities due to haphazard construction of roads and industries.

It is mostly the weak road infrastructures and industries dependent on raw materials that are the most exposed to climate change vulnerabilities. In this study, exposure indicators like the number of registered vehicles, length of Strategic Road Network, number of strategic bridges, number of airports, number of registered industries, and proportion of the industry-dependent population were found to be in increasing trends; and the districts with more exposure units—such as Kathmandu and Chitwan—were at very high exposure. The Makawanpur, Kapilbastu, Lalitpur, Banke, Kailali, Rupandehi, Sindhuli, Morang, Bara, Dhanusha, Dang, Jhapa, Saptari districts fell under the high exposure category, while districts like Humla, Mugu, Myagdi, Lamjung, Terhathum, Western Rukum, Parbat, Darchula, Dolpa, Achham, Salyan, Manang, Eastern Rukum, Bajura, Kalikot, Taplejung, Jajarkot, Jumla, Bajhang, and Dadeldhura fell under the low exposure category as these districts comprised of a lesser number of SRN, domestic airports in operation and limited industries including fewer people dependent on industries. In addition, two district headquarters (Humla and Dolpa) are yet to be connected to the road network.

The vulnerability rank of a given district is a function of its sensitivity and adaptive capacity. Even among the districts that are in the same physiographic regions or provinces, the levels of their sensitivity and adaptive capacity can differ from each other. Five districts—Chitwan, Makwanpur, Kavrepalanchok, Kathmandu, and Lalitpur—fell under the high sensitivity category. In contrast, 18 districts were found to have a very low sensitivity rank. Factors that contribute to these differences in rankings are traffic flow and congestion, percentage of population influenced by disaster per kilometer road, number of vehicles in use that are older than 20 years, the proximity of roads to landslides and floods, economic capability (GDP contribution), types of industry, and number of female employees in the industry. Stakeholder consultations revealed that "the hilly districts of Nepal located in the Siwalik, Mahabharat range, mid-lands and fore, and higher Himalayas are more susceptible to landslides because of their steep topography and fragile ecosystems".

According to the analysis conducted for this study, 11 districts—namely Kailali, Dang, Rupandehi, Kaski, Chitwan, Makwanpur, Kathmandu, Lalitpur, Bara, Morang, and Jhapa—were found to have very high adaptive capacity. The districts ranked with very high and high adaptive capacity had features such as long length of blacktopped SRN, high quality of the road, high numbers of weather-related information sharing stations, good accessibility of and to domestic and international airports, and availability of skilled manpower in industries.

Districts that mainly lie in Terai reason were ranked as having very high to high adaptive capacity, followed by the districts with a metropolitan city, such as Kathmandu, Lalitpur, Chitwan, Kaski, and Morang. These high rankings were due to the following: structural robustness, employee insurance schemes, skilled manpower in industry, proper river discharge estimation, sharing of the blacktopped road, public-private partnerships, and social security schemes. In contrast, it was the absence of these features that contributed to the low adaptive capacity ranking of the Humla, Dolpa, and Mugu districts in Karnali Province and the Doti and Bajhang districts in Sudurpaschim Province.

Seven districts—namely Dhading, Humla, Mugu, Dolpa, Nuwakot, Sindhupalchok, and Kavrepalanchok—were ranked as very highly vulnerable and 28 districts as highly vulnerable. These districts lie in the high mountain, middle mountain, and hilly regions. In contrast, most districts in the Terai region were ranked as having low to very low vulnerability, mainly because they have less sensitivity to climate change impacts due to better quality of roads and bridges and availability of skilled manpower in the industrial sector. However, some of the districts in the Terai region do fall under the medium to high vulnerability ranking as well.

The province-wise analysis revealed that in Province 1, the Dhankuta, Illam, Udayapur, and Sunsari districts were very highly vulnerable. This was due to their high sensitivity that resulted from factors such as annual average daily traffic, types and quality of roads, level of road inclination, the proportion of female employment in industry, and GDP contribution from the industrial sector. Additionally, Dhankuta also had a very low level of adaptive capacity. In contrast, the district of Okhaldhunga received a ranking of very low vulnerability, mainly due to its infrastructure and resources.

The Parsa and Rautahat districts in Province 2 received a ranking of very high vulnerability, whereas, the rest of the province's districts were ranked as having a mixed level of vulnerability. Due to the very low adaptive capacity of Rautahat and the very high sensitivity ranking of Parsa, these two districts are found very highly vulnerable among the districts in Province 2. Their vulnerability ranking was further informed by sensitivity indicators such as the number of manufacturing, construction, and agriculture- and forest-based industries, the proportion of GDP contribution, types of roads, and annual levels of traffic flow.

In Bagmati Province, the Dhading, Nuwakot, and Kavrepalanchok districts were ranked in the very high vulnerability category, while Kathmandu, Bhaktapur, and Ramechhap were ranked in the very low vulnerability category. Differences in the levels of vulnerability were related to differences in regulations on the 'green sticker', size of strategic road network being blacktopped, quality of existing roads, and the number of skilled manpower in small cottage industry.

In Gandaki Province, the Lamjung, Tanahu, and Gorkha districts were ranked in the very high vulnerability category, whereas Myagdi and Baglung were ranked in the high vulnerability category. In contrast, Kaski was ranked as having very low vulnerability due to its higher level of adaptive capacity resulting from factors such as road quality, skilled manpower availability in the industry, and airport facilities.

In Lumbini Province, the Eastern Rukum, Rolpa, Piyuthan, and Gulmi districts were ranked in very high vulnerability category, whereas Bardiya, Dang, and Arghakhachi were ranked in the high vulnerability category. Sensitivity indicators like kilometers of earthen road, an inclination of the road more than 300 (40 to 60), and types and scale of industries played a key role in determining the differences in vulnerability ranks among districts. Similarly, the topography, especially the proximity of physical infrastructure to landsides, also played a vital role in increasing the vulnerability rank of some districts like Rolpa, Pyuthan, and Gulmi. In Karnali Province, Humla and Mugu were ranked very high in terms of vulnerability, whereas Dailekh and Dolpa ranked high. However, at the national level, the Humla, Mugu, and Dolpa districts were ranked as having very high vulnerability.

In Sudurpaschim Province, the Bajhang and Doti districts were ranked as being very highly vulnerable, whereas Darchula fell under the highly vulnerable category. But in a nationwide (rather than province-wide) comparison of districts, these three districts fell under moderate and low vulnerability categories. In general, the provinces of Karnali and Sudurpaschim have high sensitivity and very low adaptive capacities, making their districts highly vulnerable to climate change. For example, the connectivity of roads in the upper belt of Karnali Province is very poor whereas the quality of roads is poor in high-mountain and the middle-mountain regions of Sudurpaschim. Similarly, features and conditions related to the proximity of current road infrastructure to landslides, geographical structures, air transport facilities, and social security schemes in the upper belt of Karnali and Sudurpaschim Provinces make them more vulnerable.

The identified key climate change stressors in these sectors, like change in precipitation, change in extreme wet days, change in consecutive wet days, and temperature change, played a significant role in determining the risk rankings of different districts. The Dhading, Makawanpur, Nuwakot, Sindhupalchok, Lalitpur, Kavrepalanchok, Sindhuli, Chitwan, Parsa, and

Kathmandu districts appeared to have a very high risk, whereas Sunsari, Dolakha, Rautahat, Bardiya, Tanahu, Udayapur, Kailali, Siraha, Rupandehi, Dang, Sarlahi, Mahottari, and Saptari were ranked as having high risk. The districts under the very high risk category are mainly in Bagmati Province, whereas the districts with low to very low risk rankings are in Karnali, Sudurpaschim (except Kailali), and Gandaki Provinces (except Tanahu). These differences in levels of risk were informed by exposure indicators like the length of SRN, number of strategic bridges, number of industries, and number of employees in the industrial sector.

Risk in the ITPI was projected for RCP 4.5 and 8.5 in the medium term (2030) and long term (2050). Under RCP 4.5, the medium term showed very high and high risk levels, mostly in Bagmati Province (except in the districts of Bhaktapur, Rasuwa, and Ramechhap). In the long term, districts in Lumbini Province and Province 1 also came under high risk. The main reason for this is the likely increase in climate extreme events such as an increase in temperature, uneven precipitation, increase in warm days, and increase in extreme wet days.

Under RCP 8.5, in the medium term, the overall risk scenario observed was similar to RCP 4.5 (2030), where most of the districts got very high and high risk ranks in Bagmati Province except for Bhaktapur, Rasuwa, and Ramechhap. Province 2 and Province 1 fell under the high risk category. In the long term period under RCP 8.5, more districts (except Ramechhap) in Bagmati Province got very high and high ranks. Besides, in Province 2, three districts fell in very high risk category, while the remaining five districts fell in high risk. Lumbini Province is expected to have a high to moderate level of projected risk. However, in all four projection models, risk levels were observed to be comparatively low in most of the districts in Karnali Province and Sudurpaschim Province. In terms of physiographic regions, the risk was assessed to be comparatively very high in the in hill, Siwalik/Chure and Terai regions, followed middle-hill and high-mountain districts.

The overall trends show that future climate change will aggravate the risk from climate change impacts in the ITPI. At the baseline, ten districts were in the very high risk category, but in the long term for RCP 8.5 (2050), 16 districts were projected to come under the very high risk category. Only 15 districts in RCP 8.5 (2050) will have low risks from climate change impacts in the ITPI.

There is no one-size-fits-all solution in terms of addressing risks and vulnerabilities in the ITPI. Therefore, the adaptation options identified in this study include those for short, medium, and long terms. Examples of options for the short term include, among others, promoting circular economy and industrial ecology concepts to improve resilience and sustainability in the industrial sector; carrying out practical research on adaptation measures, both for current transportation systems and the design of new systems and infrastructure; and developing alternative routes and transportation mechanisms to rescue people and ensure that stranded passengers get to their destinations. Medium-term adaptation options include setting up roadside safety signs in areas susceptible to landslides, floods, and fires; establishing early warning and hazard communication systems for commuters and drivers and disseminate information through SMS or ICT means; adopting the Resource Efficient and Cleaner Production (RECP) approach in the sectors to make industrial production more sustainable; and making provisions for mandatory inclusion of climate risk management in all industries during the design and planning phase. Long term adaptation options include formulating guidelines and policy related to health insurance to support laborers working in the sector; developing alternative routes and ensuring regular maintenance and monitoring to enable transportation of goods during emergencies; promoting practices to increase slope stability and reduce erosion, such as reducing gradients of roadside slopes, constructing masonry retaining walls, and planting trees and vegetation along roadways; and integrating climate-resilient building practices into the construction and maintenance of key airports, national highways, and connecting roads.

This study is the first of its kind to assess climate change-related vulnerabilities and risks in Nepal's ITPI, and identify relevant adaptation options, thus establishing a baseline for this sector. To build upon and utilise this work further, it is recommended to carry out several in-depth studies and research in the industry, transport, and physical infrastructure sectors separately. Further recommendations include the following: (i) increase investments in sectoral capacity building; (ii) fill data gaps in the ITPI; (iii) facilitate easy accessibility of information needed to conduct more comprehensive analyses; and (iv) increase the scope of VRAs in the future to include local-level information (which due to data unavailability this study could not).

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Chapter 1

Background and Sectoral Context

1.1 Background

Industry, Transport, and Physical Infrastructure (ITTPI) are key sectors contributing to the country's economic growth, mobility, and future development. The industrial sector creates jobs and provides employment opportunities to the people. The industry accounts for 13.45% of Gross Domestic Products (GDP) providing 13.15% of total employment as of 2018 (OECD, 2019) of which about 90% is from the cottage and small industries (DoI, 2020a). Similarly, the transport industry alone provides direct employment close to 20,000 people and 10.6% of the contribution to real GDP (IBN, 2017).

A. Industrial Sector

In Nepal, industrial production represents a small variety of economic activities. The country's history of industrial development is short. In 1936, after the formulation of the Nepal Companies Act, Biratnagar Jute Mill was established as the first joint-venture industry. The National Industrial Development Corporation (NIDC) was institutionalized in 1959 but it was only after the 1980s that Nepalese economic reform took place with special consideration paid to industrialized growth (Khanal et al., 2005). Only 15 manufacturing industries were registered under the industrial department until 1990. However, currently, there are altogether 8,247 industries that have been registered up to FY 2019/20. Table 1 below shows an overview of the different categories of industries in Nepal, registered under the Department of Industry (DoI).

Table 1: Industries Registered by category (FY 2019/20)

Category of industry	No. of units
Agro- and forestry-based	478
Construction-based	58
Energy-based	421
Information-technology	76
Manufacturing	3,091
Minerals	69
Services	2236
Tourism	1,823
Total	**8,247**

Source: DoI, 2020a

B. Transport and Physical Infrastructure sectors

Distance, density, and division are three dimensions of development. Distance is an important dimension for balanced economic development. Research shows that investment in the transport sector contributes to reduced transportation costs, especially travel duration. Additionally, transport and its physical infrastructures play a pivotal role in industrial growth and have been playing a strong role to increase the economic development of Nepal. The development of the country's road transport network began with the import of automobiles in Kathmandu around 1901. Throughout history, major milestones in transportation technology have stimulated economic progress and extensively improved people's quality of life. The Government of Nepal (GoN) has identified and prioritised 15 key sectors where investment is needed to graduate the country from 'least developed' to 'developing' country by 2022, with transport being one of them (GoN, 2014b).

Two modes of transportation are common in the country: air and road. Road transport is the predominant mode, accounting for 90% of the movement of passengers and goods. Currently, however, roads are often congested and not properly maintained, often resulting in high vehicle operating costs. The demand for air transport is increasing as services become more accessible and affordable. 47 airports are functional countrywide, with sizable and frequent traffic (CANN, 2020). The annual average growth rate of vehicle registration in Nepal is 14%. Around 4% of the total share of registered vehicles are private, and another 4% are used for public services (DoTM, 2020).

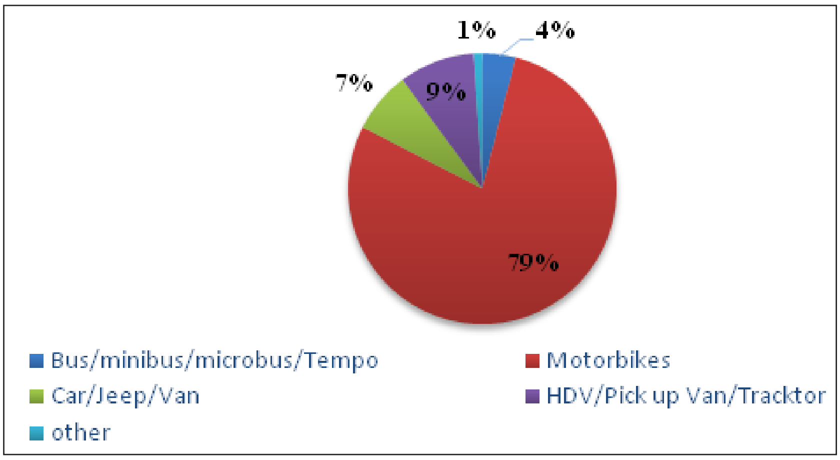


Figure 1: Share of vehicle types in Nepal

Figure 1 shows the share of vehicles by type in Nepal. The number of registered vehicles in the country has reached 3,823,108, which is significantly connected to the increasing trend of greenhouse gas (GHG) emissions of Nepal (see Figures 2 and 3). Further, 30,088 km of the road network (strategic and local roads) have been constructed by the end of FY 2017/18 (GON, 2019).

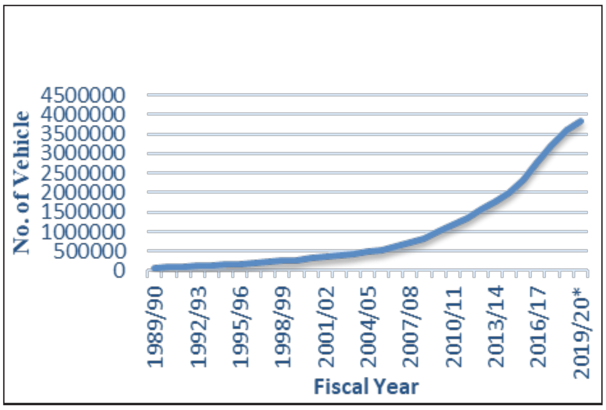


Figure 2: Vehicle registration trend in Nepal

(Source: DoTM, 2020)

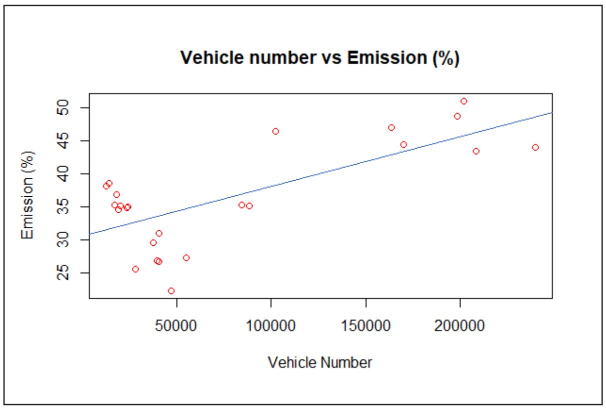


Figure 3: Correlation between vehicle registration and GHG emission trend

1.2 Challenges in ITPI sector

The economic prosperity of Nepal depends on the development, expansion, and promotion of its industrial and transport sectors. However, the functioning and sustainability of the industrial sector and the construction of roads have been major challenges in Nepal. Limited sustainability planning in and of industry, in addition to poor transport infrastructure, has often triggered climate extreme events such as heavy rainfall, massive landslides, and floods. The following sections highlight challenges specific to the ITPI in Nepal.

1.2.1 Safety and compliance

Safety and compliance issues include the haphazard building of roads without cognizance of risks. 'Good' rural roads are still not being built. In the building of local roads, the basic requirement for considering geology, hydrology, and engineering is relegated to the periphery. Given the 'local' status of these roads, seeking the inputs of geologists, hydrologists, or road engineers in their making is not the norm and perhaps considered impractical or unnecessary. Moreover, local governments pursuing roadbuilding have no access to experts or lack sufficient capacity in project planning, design, implementation, or management. However, with subsequent governments increasing the funds transferred to local governments, the momentum of local roadbuilding continues at an accelerated rate.

The construction of roads in any given landscape has multiple implications for both ecosystems and societies (Dixit & Shukla, 2017). Before a road is built, surface runoff in the landscape is normal, but later this runoff is re-channeled to new areas. The construction of roads also disrupts the balance of springs. When a flow path is disturbed, water no longer flows towards the spring and soon retards the groundwater recharge. Most community-based drinking water supply schemes in Nepal rely on springs as their main source. Spring-fed streams are also used for small-scale irrigation. Thus, the decline in spring flow associated with non-engineered roadbuilding negatively impacts community-based drinking water and local irrigation schemes, exacerbating local-level water and food insecurity. Although environmental impact assessments of roads include mitigation of adverse impacts as one of the steps, compliance remains a major gap. Also, the interdependence of local hydrology and road building is poorly recognized in most road designs and often ignored during implementation. The outcomes of such practice are drainage failure, fractures, and debris flow (McAdoo et al., 2018). Furthermore, roads are often damaged immediately after being built, driving the costs of maintenance, rehabilitation, and rebuilding through the roof.

1.2.2 Likelihoods of natural disaster and vulnerabilities

The geography of Nepal itself plays a prominent role in its susceptibility to natural disasters. Places with elevations between 2,000-2,500 meters experience the highest amounts of landslide occurrences. Landslide occurrence is also related to slope angle: the higher the slope of a road, the greater the likelihood of landslides there (Xu et al., 2017). Therefore, the current practice of building poorly designed road infrastructures and excavator-led design increases the landslide-proneness of several areas. The prevailing cut-and-throw approach has altered the landscape, negatively impacting drainage, slope stability, erosion, and downstream sediment supply.

Additionally, most of the roads in the hilly region in Nepal, aligned along riverbanks, face disruptive effects. Rivers flowing along the curves of riverbanks result in the toe cutting of slopes, erosion, and saturation of landmasses, which can trigger landslides. Past landslides in Jogimaara, the Krishnabhir one on the Prithvi highway, and the one in Mankha Jure on the Arniko highway are well-known examples of roadside slides. In some of these cases, the sudden landslide or rockfall along the highway damaged vehicles and caused loss of life (Nagarik News, 2017).
Risks related to roadbuilding can be avoided but are not due to a lack of strict regulations. Many roads are constructed, but not repaired or maintained regularly and usually come with a total absence of proper drainage, haphazard destruction of wide swathes of vegetation, and downhill soil dumping. Together, this situation invites a high likelihood of natural disasters and vulnerability, with prospects of huge economic losses in repairing roads along with losses of human life (GoN, 2020a).

1.2.3 Mal-development practices

The political economy of road construction in Nepal is complex. Many political leaders entice people with the promise of better road infrastructure out of political and self-serving motives. In reality, these promises mean and yield nothing. Only some road projects are intended to create public good; most others are to make individual profits. The fact that 33% of the elected local representatives are associated with the construction industry highlights the inbuilt conflict of interest in the political-economic imperative of road building in Nepal (CIJ, 2019). Road contractors are very interested in construction as a means of cash flow, which results in a lack of proper road design at the provincial and municipal levels. There is also a lack of timely monitoring and supervision that is necessary for the construction of engineered local roads. Given this, the biggest challenge is to incorporate the experience of the DoLIDAR with proper structural design (physically and environmentally) in the development of local infrastructure into newly formed provincial and municipal bodies.

A report prepared by the Institute for Integrated Development Studies (IIDS) and the Confederation of Nepalese Industries (CNI) in 2019 assessed Nepal's infrastructure quality gaps. It highlighted the need to increase investment and funding, and detailed limitations related to the development of road infrastructure. It described the following key challenges:

- The under-utilization of existing networks
- The administration-driven, rather than economic/strategic, classification of roads
- The vulnerability of road networks to climate change and disasters
- The difficulty of maintaining existing road networks due to ineffective asset management, which in turn results in high maintenance costs
- The traditional approach to road construction (cutting high slopes and filling valleys)
- The absence of short and long term plans for and progress reports on projects dictated by available resources (or budget allocation)

1.2.4 Emissions

The ITPI contributes to greenhouse gas (GHG) emissions in Nepal. Industries related to brick, cement, and metal, other manufacturing industries, and the food and beverage industries are the major contributors of emissions. Manufacturing industries emit 2,248 Gg of CO_2-eq. and is the largest contributor of CO_2 (48%) within the energy sector and the second-largest contributor of total GHG (17%) emitted countrywide. In contrast to its significant contribution of GHG emissions, the industrial sector's contribution to national GDP has been continually shrinking, especially after 1996. At that time the value added to national GDP was reported to be 21.49% while fell to less than 10% by 2017(OECD, 2019). Therefore, as can be seen in Figure 4 below, there is a striking contrast between how much the industrial sector adds value to the GDP of Nepal and how much it contributes to the country's GHG emissions,

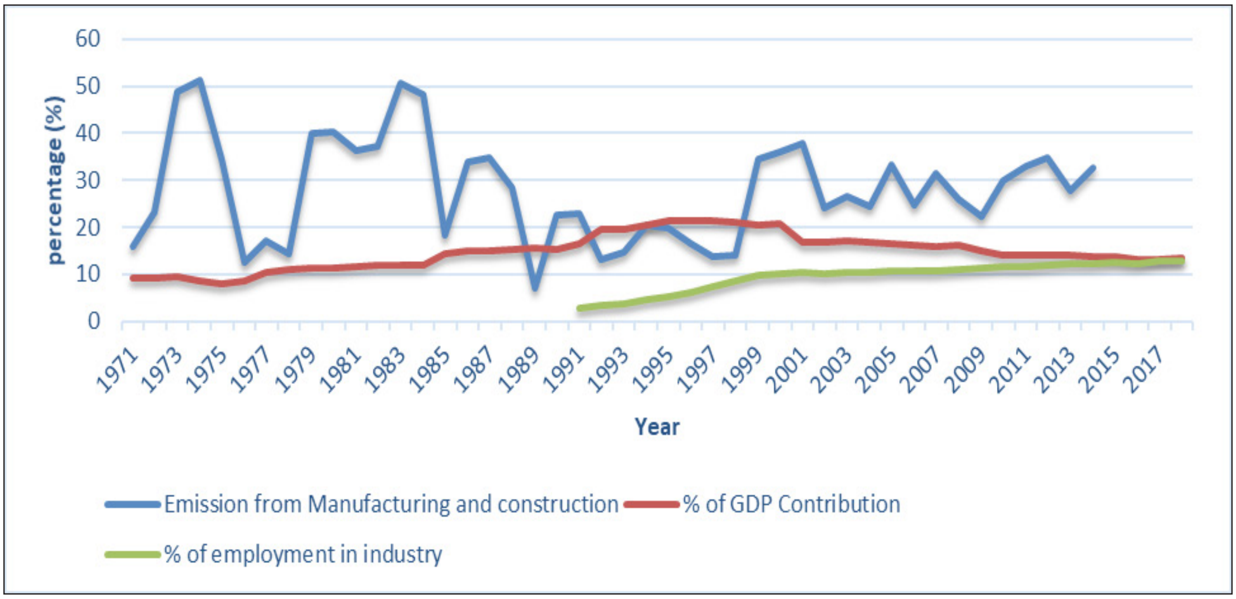


Figure 4: Environmental and economic contribution from the industrial sector
Source: World Bank and OECD national accounts data 2019, ECD/IEA 2014

Based on Nepal's GHG inventory, emissions (CO_2eq in Gg) from fossil fuel combustion in the transport and industry sectors contribute to 13% and 17% of total emissions respectively. Within the transport sector, the main sources of GHG emissions are heavy vehicles such as trucks, tankers, and lorries, followed by light-duty vehicles such as cars, jeeps, and vans (see Figure 5) below.

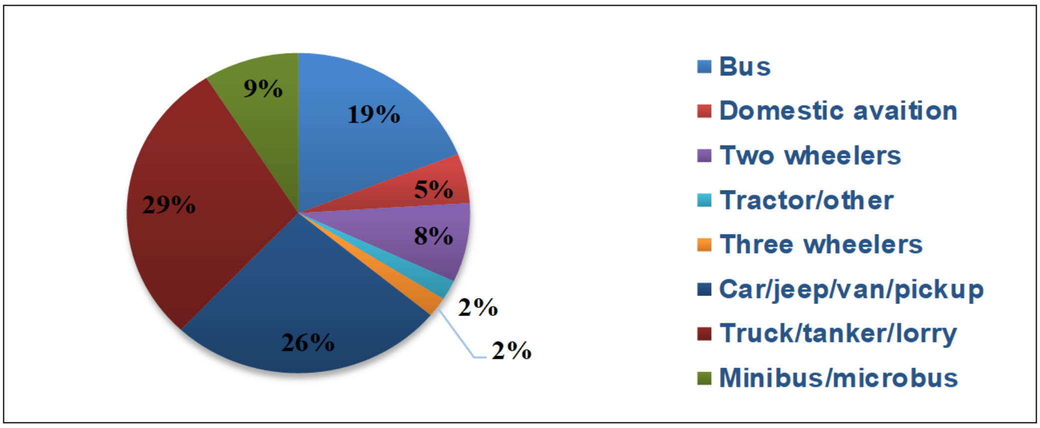


Figure 5: CO2 emission share by subsector of transportation

Source: Nepal's GHG inventory, 2017

Although two-wheelers make up about 79% of the total vehicle fleet, their contribution to the overall GHG emissions from the transport sector is estimated to be only 8 percent as shown in Figure 5 (CDES, 2017). From 2001 to 2016, industrial emissions tripled and emissions from transport more than quadrupled. In contrast, the increase in emissions from private households, though still a dominant source, was only marginal over the same period (Sadavarte et al., 2019). However, the Third National Communication Report (CDES, 2017) showed that if the country experienced a medium GDP growth rate of 5.6 percent, along with interventions in the transport sector in the form of mass transportation systems and introduction of electric and bio-fuel transportation technologies, among other initiatives, there would likely be a significant reduction in GHG emissions by 2030 (see Figure 6 below).

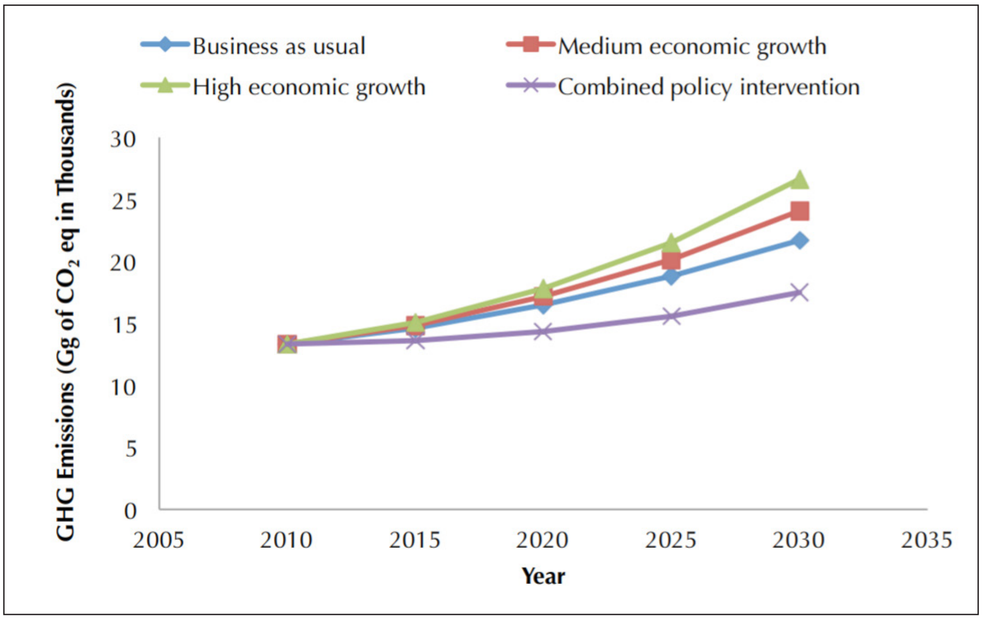


Figure 6: Total GHG emissions projection under various scenarios

Source: CDES, 2017

1.2.5 Climate change vulnerability and risks

In addition to all other challenges, an increase in the average temperature and rainfall levels has a substantial impact on the planning and operation of roads. The Nepal Sustainable Transport Strategy (NSTS) 2015 examined the impact of climate change on the transport and (transport-related) physical infrastructure sectors and found that the infrastructure constructed over the last six decades is more susceptible to rapid changes in climate because of its traditional design and implementation. Poor road conditions correlate to high transaction costs and economic loss. As a result, the expansion of economic opportunities becomes confined.

Given the above, it is clear that this VRA of Nepal's ITPI is crucial for understanding current vulnerabilities and risks within these sectors, and for identifying relevant adaptation options and mitigation targets. It is hoped that this report will ultimately improve the preparedness of these sectors to deal with current and future risks.

Chapter 2

Objectives and Scope of the Study

2.1 Objectives of the study

The overarching objective of this study is to assist the formulation of Nepal's National Adaptation Plan (NAP) by conducting an assessment of current and projected impacts of climate change on the country's ITPI and associated vulnerabilities and risks so that sector-specific adaptation policies and plans can be identified and formulated. Specific objectives include:

- Assessing risks and vulnerabilities to climate impacts across the ITPI and different physiographic regions through applicable frameworks; and ranking/ categorizing these risks and vulnerabilities.
- Identifying adaptation options, at multiple scales (district, province, and physiographic regions), to address priority risks and vulnerabilities.

2.2 Rationale of the study

In many of the Least Developed Countries (LDCs), transport-related difficulties have acted as a bottleneck that has inhibited and retarded their pace of industrialization. Developing nations have invested between 15 to 35 percent of their national budgets on transportation infrastructure, of which three-quarters are spent on roads. Despite this, transport networks are only growing at a rate of 0.2 to 9.5 percent in length. Additionally, the density of road networks in developing countries is only about 10 percent of that in developed countries (Mckibbin & Henckel, 2017).

Until recently, countries like Nepal have not had much of a focus on how climate change impacts their ITPI, with barely any policies and actions planned for these issues. Transport-related investments and policies depend on a variety of physical and non-physical factors that are not well understood in the country and hence not taken into account during infrastructure design and implementation.

Additionally, there is often a risk that transport investments are designed in ways that are not cost-effective and do not produce expected outcomes.

Given how vitally the ITPI supports Nepal's development, it is extremely important to understand and address climate change impacts and associated sector-specific vulnerabilities and risks. Transport infrastructure, particularly road systems, is lacking in agrarian communities that are host to agricultural production and often located in rural areas. The little that is available is in poor condition (Goyol & Pathirage, 2017). These conditions make the infrastructure vulnerable to existing climate risks and related future uncertainties. This is unfortunate because well-established road systems are generally associated with global economic growth as they help improve agricultural productivity and reduce poverty.

Studying climate change risk in the ITPI can enable the option of using higher climate adaptable design standards and road construction materials, change and/or modification of existing hydraulic structures, and flood protection measures. Towards this end, this study was intended to identify relevant ITPI sector-specific climate-change related risks and vulnerabilities and offer adaptation options that will help in stimulating growth in efficient ways that can also reduce poverty and address social costs.

2.3 Scope of the study

This assessment report provides a detailed and representative description and analysis of the climate change vulnerability, impacts, and adaptation options for two broad areas—i) Industry and ii) Transport and Physical Infrastructure—covered in this report are illustrated in Figure 7 below. The 'Industry' area mostly included operational industries, including small cottage industries. Additionally, investment scales (large, medium, and small), working populations, and GDP contributions related to these industries were considered. On the other hand, the 'Transport and Physical Infrastructure' area included air and road transport, and roads, bridges, and airports. This assessment relied on an indicator-based approach to categorize hazards, exposures, vulnerabilities, and risks.

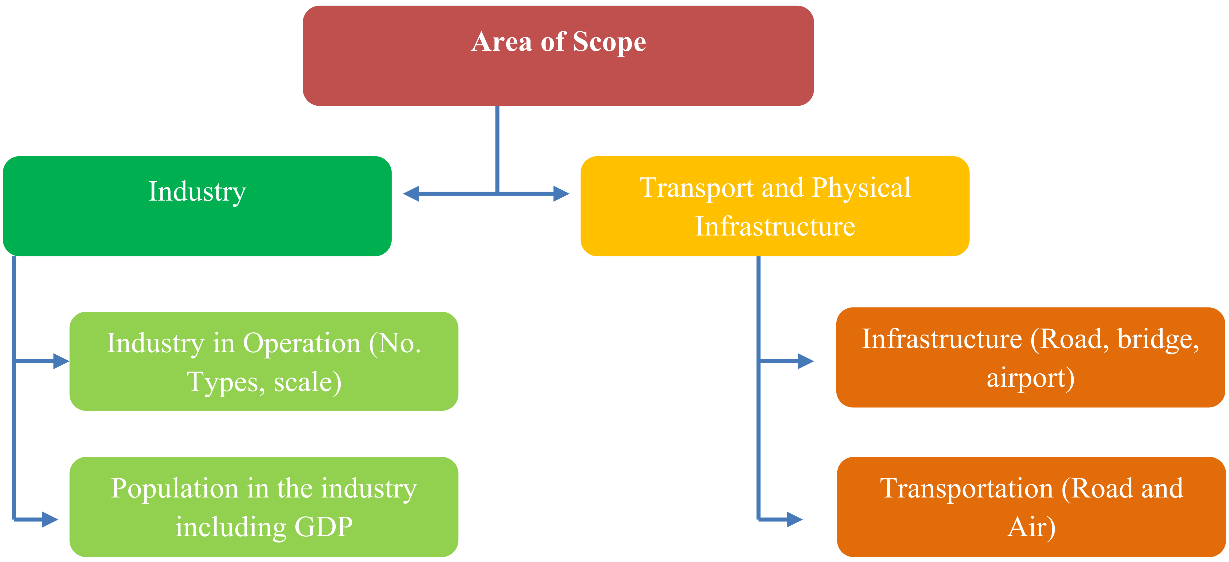


Figure 7: Scope of the study

Chapter 3

Methodology

3.1 Framework

In 2017, the Government of Nepal published the VRA framework and indicators for the formulation process of its National Adaptation Plan (NAP). This framework—based on the Fifth Assessment Report (AR-5) by the Intergovernmental Panel on Climate Change (IPCC, 2014) and the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)—has also been used in this report.

The aforementioned framework unpacks the element of risk and customizes it, as applicable, to the national context. It assumes that the risk of climate-related impacts results from the interaction between climate-related hazards (including hazardous events and trends) and the exposure and vulnerability of human and natural systems. Changes in the climate system (trends and scenarios), biophysical system, and socioeconomic processes (including governance and adaptation and mitigation actions) are the drivers of hazards, exposures, and vulnerabilities. Following this framework, this VRA is based on measurable and quantifiable data available from primary and secondary sources. Figure 8 below summarizes the framework adopted for this assessment.

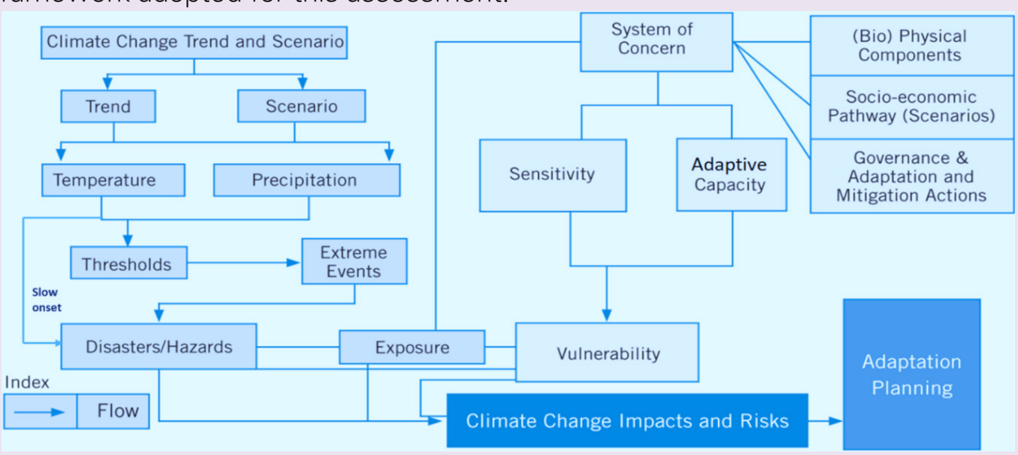


Figure 8: Climate change vulnerability and risk assessment framework

Source: MoPE, 2017

3.2 Approach

For this VRA, a mix of top-down and bottom-up approaches was used.

- **Top-down approach** involved long term national and regional climate change modeling, impact projections, and adaptation strategies, identified through technocratic cost-benefit analyses (Kelly & Adger, 2000).
- **Bottom-up approach** involved a consultative process designed to empower local and provincial government and stakeholders, including communities, by encouraging self-assessment of climate impacts methods (Aalst et al., 2008). This approach is useful in checking and validating information derived from top-down approaches.

3.3 Methodological steps

The methodology used in this study consisted of nine steps based on the VRA framework of the NAP process, summarized in Figure 9 below.

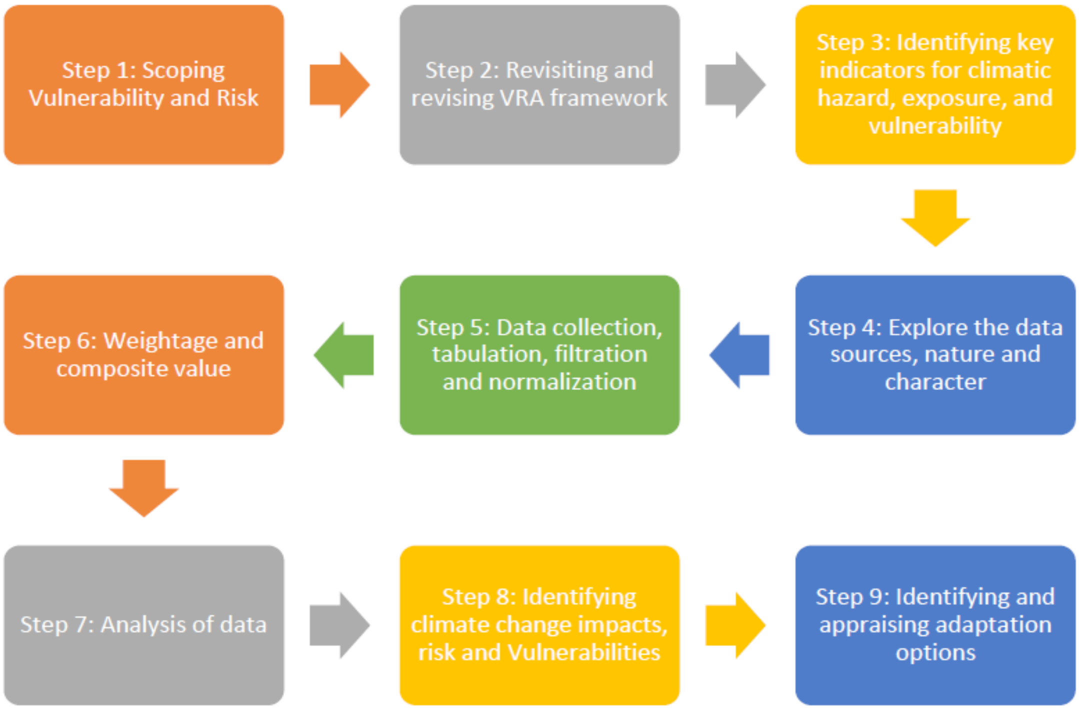


Figure 9: Steps of vulnerability and risk assessment (MoPE, 2017)

Step 1. Scoping vulnerability and risk: The scoping task was an important step to set the boundaries for the VRA methodology. This process involved stocktaking of existing methodology, approaches, and frameworks for undertaking VRAs. It also helped in understanding the various concepts methodologies and terminologies used by the IPCC, NAP technical guidelines, and UNFCCC reference documents.

Step 2. Developing the VRA framework: The NAP technical guidelines allow countries to develop their country-specific frameworks for assessing vulnerability and risk. This study used the VRA framework developed by Nepal to assess and illustrate the logical linkages between hazard, exposure, vulnerability, and risk. Additionally, it included mapping of adaptation options. A 'slow-onset event' was added as an amendment to the framework.

Step 3. Identifying key indicators for hazard, exposure, and vulnerability (sensitivity and adaptive capacity): This study used an indicator-based vulnerability assessment, which is among the most common and easy-to-conduct climate vulnerability assessment methods. The report titled "Vulnerability and Risk Assessment Framework Indicators for National Adaptation Plan (NAP) Formulation Process in Nepal" and published by MoPE (2017), was the main source from where the indicators were selected. Given that this ITPI' VRA is the first of its kind, several works of literature—including IPCC reports, DHM reports on climate change trends and scenarios, journals, and articles—were reviewed to make this study more coherent and to identify climate extreme events and indicators for hazards, exposures, sensitivity, and adaptive capacity. In addition, the resultant list of indicators was used to gather secondary data from many other institutions.

Step 4. Exploring data sources: The main data sources were government and development agencies, private sector associations, individual experts, and researchers (see Table 2). Most of the data were collected from annual reports, research studies, policy briefs, periodic plans, and strategy documents. Some data was also collected from peer-reviewed articles and journals.

Table 2: Data types and sources

Data source	Name of organizations	Data collection documents (Source types)
Government organizations	MoPIT, DoTM, DoR, DoLIDAR, NOC, TIA, CBS, NIB, ATC, CAAN MoICS, DoI, IIPD, IIED, DoCSI,	Reports (periodic, annual, and progress reports), research findings, policy briefs, action plans, and strategies, peer-reviewed journals, and articles
Development organizations	ICIMOD, ILO	
Private sector associations	FNCCI and NADA	

Step 5. Data collection, tabulation, filtering, and normalisation: The collected data and information were validated through consultations in all seven provinces and with the Thematic Working group and sector-specific experts at the national and international levels.

The spatial data was available in vector and raster formats, while non-spatial data was available in tabular format. Both spatial and non-spatial data were then tabulated in the uniform format. This was then compiled in Excel according to hazard, sensitivity, and adaptive capacity indicators for different physiographic zones, districts, and provinces. Data filtering was done by ranking, clustering (grouping), imputing (substituting some values for missing data), and sorting data (mainly categorical and nominal data) for individual variables by different responses (e.g., gender). Data transformation was carried out where appropriate.

To make them consistent and comparable, all quantitative data was normalized using the following formula, which converted all values to a value ranging between 0 and 1:

$$X_{i,0to1} = \frac{X_{\max} - X_i}{X_{\max} - X_{\min}}$$

where,
X_i represents the individual data point to be transformed
X_{min} is the lowest value for that indicator
X_{max} is the highest value for that indicator
$X_{i,0to1}$ is the normalized data point within the range of 0 to 1

Steps 6 and 7. Weightage and composite value, and analysis: Weightage was calculated for each indicator based on expert opinions. These expert opinions were obtained using the Analytical Hierarchy Process (AHP) tool (Hossain et al., 2014; Likert, 1932), which allowed experts to score the indicators between 1 (lowest score) to 9 (highest score) based on their relative importance.

The aggregation was performed using the weighted linear summation method which is a linear combination of standardized values using weights as shown in the equation below.

$$AC = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}$$

where,
AC is an aggregated indicator, for example, aggregated adaptive capacity
x_i is an individual indicator of the adaptive capacity
w_i is the weight assigned to the corresponding indicator x_i (The most preferred alternative is that with the minimum value of AC)

The indicators of exposure, sensitivity and adaptive capacity, along with their weightage are presented in Annexes 1, 2, and 3.

Step 8. Calculation of the vulnerability and risk indexes: According to the IPCC AR-5, vulnerability is a function of sensitivity subtracted from adaptive capacity, whereas risk is a multiplicative function of hazard intensity, exposure, and vulnerability. In line with this, vulnerability and risk indexes were calculated by using the following equations:

$$V = S - AC$$

where,
V is the composite vulnerability indicator,
S is the sensitivity component of vulnerability,
AC is the adaptive capacity component of vulnerability
and

$R = H_{intensity} \times V \times E$

where,
R is the risk index
$H_{intensity}$ is the hazard intensity
V is the vulnerability
E is the exposure.

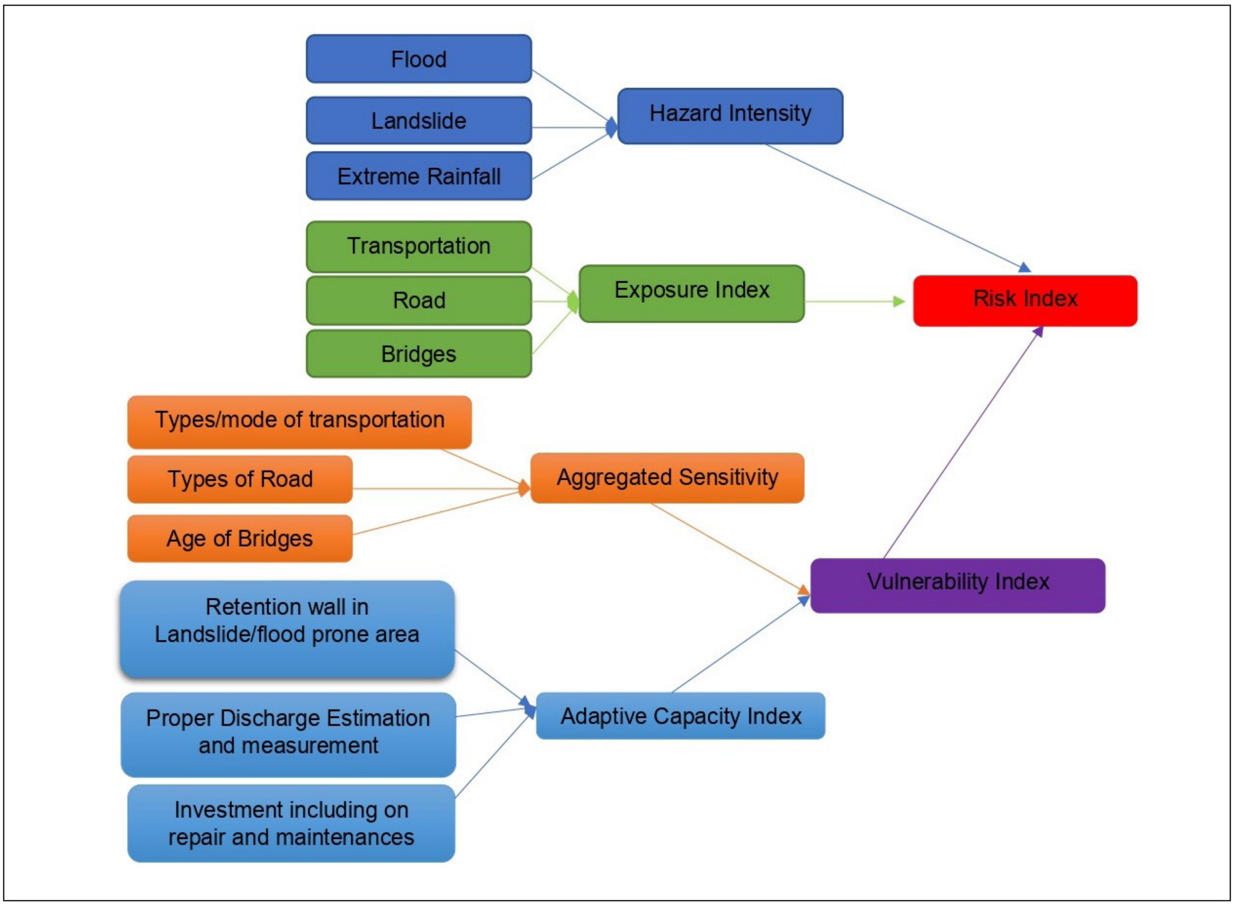


Figure 10: Example for weightage, normalization, and index calculation

Step 9. Identification of adaptation options: Based on the information generated from ranking vulnerabilities and risk, relevant adaptation options that address problems through the management and operating strategies, infrastructure changes, policy adjustments, capacity development, and generating awareness were identified. This identification was done using criteria that are in line with national goals and targets as well as national and sectoral policies relevant to climate change.

The process for the identification of adaptation options included the following steps:

- Potential adaptation options were identified based on the impacts, vulnerability, and risk maps and tables generated by the analysis of secondary data.
- A list of potential adaptation options was identified based on a literature review of successful adaptation practices, effective local knowledge and practices, efficient technologies, and common practices.

- A consultation was carried out with relevant experts to map effective adaptation strategies in the relevant sector and sub-sectors.
- Consultations at the province level were carried out to identify adaptation options in the context of existing risks and vulnerabilities.
- Validation of adaptation options was done through Thematic Working Groups (TWGs) and Technical Committees.
- Following all the above, the list of adaptation options was finalized.

Chapter 4

Observed Climate Change Impacts on the Industry, Transport, and Physical Infrastructure

The industry and transport sectors are vulnerable to extreme weather and climate change (Hooper et al., 2014). The industrial facilities that are located in climate-sensitive areas (such as fragile mountains and floodplains), dependent on climate-sensitive inputs (such as food processing), and with long-lived capital assets are in the frontline about climate impacts (Ruth et al., 2004). The IPCC Fourth Assessment Report (AR-4) predicted that weather patterns in South and Southeast Asia would become dominated by rainfall and increased temperatures, which would cause significant disruption to transport operations. Climate change related hazards (such as floods and landslides) have the potential to seriously impact Nepal’s transport infrastructures, affecting the movement of people, industrial products, and other goods.

Generally, the construction of transport infrastructure is informed by design standards that consider very specific temperature and precipitation ranges and return intervals for extreme events, such as floods and extreme heat. If weather conditions diverge from the initial accounting done during the design stage—something that could occur more frequently with climate change—the infrastructure becomes likely to malfunction. Therefore, it is important to design transport networks that are not only ‘climate-proof’ from a design perspective, but also able to foster broader climate resilience for the community.

Climate change impacts are also particularly pertinent to the ITPI given the lifespan and the high initial cost of their infrastructures, as well as their essential role in the functioning of societies and economies. Among infrastructure types, roads that are typically constructed from impermeable materials are particularly susceptible to surface water flooding. An increase in the number of very hot days could lead to an increase in road infrastructure failures. Additionally, drier and hotter summers may cause pavements to deteriorate (Vogel et al., 2017). Air transportation is as vulnerable to extreme climatic events as road transportation. For example, changes in temperature affect aircraft performance, infrastructure, and demand patterns, while changes in precipitation patterns can increase delays and cancellations of scheduled flights (CAPA, 2019).

In order to be more specific, climate change impacts on Nepal's ITPI sector can be divided into the following categories:

4.1 Biophysical impacts

The physical infrastructures in Nepal are impacted by floods, mass wasting, debris flow, sedimentation, rise in groundwater levels, rain, and windstorms. Common problems include collapse of industrial buildings and properties; increased exhaustion of infrastructures; silting of drains; increased instability of land through the weakening of riverbanks, hill toes, or land subsidence; inundation; and submergence of infrastructures. Extreme or heavy precipitation often leads to the washout of road infrastructures every year, while increased temperatures increase the vulnerability of pavements with a surface layer of asphalt concrete (UNECE, 2019).

Climate trends show that the annual maximum temperature in Nepal has increased, which can result in overheating of vehicles, deterioration of tires, and disturbances in daily services. Moreover, extreme climate events are triggering huge economic losses in the transportation sector due to accidents and physical damages.

The increase in temperature and the melting of glaciers often cause flash floods that wash out the roads. High temperatures also cause increased fatigue of the bituminous pavements; deterioration of gravel surfaces; thermal expansion of bridges; buckling of joints of steel structures; et cetera. During temperature drops, the infrastructure becomes vulnerable to snow conditions. High rainfall and flooding caused significant damage to road drainage structures, breaching of road embankments, scouring of bridge foundation; washouts, et cetera. Apart from climate change impacts, impacts from natural disasters (such as earthquakes and landslides) have also been significant in Nepal, causing major road blockages and failures. Table 3 below summarizes different hazards and their impacts on the infrastructure sector in Nepal.

Table 3: Hazards and their impacts

Hazard	Impact
Extreme Temperature	Road • Increased exhaustion of bituminous pavement, resulting in additional maintenance costs • Deterioration of gravel surface due to excessive moisture loss, leading to an additional cycle of resurfacing Bridge • Thermal expansion of bridges • Buckling of joints of steel structure
Flood and Landside	Road • Higher corrosion activity at locations with high humidity • Damage to road drainage structures, including foundations, due to high runoff • Breaching of road embankments, resulting in loss of road sections • Submersion of roads • Failure of embankment and drainage structures Bridge • Scouring of bridge foundations • Submersion of bridges • Bridge washout

Source: UNCRD, 2015

Due to heavy rainfalls, the mountainous region of Nepal is prone to landslides, mudflows, debris flows, and rock-falls, which can block the flow of traffic and damage road infrastructure. Over the last few decades, Nepal has experienced unprecedented heavy rains and massive floods followed by long spells of drought. The heavy rains followed by the floods of 1974, 1981, 1993, and 2004 caused substantial damage to road assets, including bridges, in various parts of the country.

In 1993, central Nepal experienced a massive cloudburst that seriously affected the Prithvi and Tribhuvan highways. The resultant rainfall created flash floods that washed away six bridges along the highways and severed connectivity to Kathmandu. The Kathmandu Valley remained isolated, due to a loss of land transport connection, for 21 days from the rest of the country. Similarly, in 1998, the western Nawalparasi District faced a very wet monsoon. The heaviest rainfall measured at 340 mm in 24 hours. Further, in August 2000, a land failure in Krishnabhir led to the closure of the key arterial road linking Kathmandu with the Terai plains for 11 days, effectively closing off (road-based) access to India as well. Naturally, this resulted in serious economic disruption in the capital city. Additionally, 140 mud slumps occurred in the 14-kilometer-long stretch from Arung Khola to Bardhghat in the Siwalik Hills (NCVST, 2009).

Several analysts have attempted to examine the relationship between rainfall thresholds and landslide initiation. Dahal and Hasegawa (2008) collated data related to 677 landslides that occurred in Nepal from 1951 to 2006, then compared the rainfall data from 193 of these landslide events to yield a threshold relationship between rainfall intensity, rainfall duration, and landslide initiation. They found that when daily precipitation exceeds 144 mm, the risk of landslides on mountain slopes is high and that a steep landscape saturated by antecedent rainfall is susceptible to landslides even with a small amount of intense rainfall. These facts illuminated the temporal and spatial character of rainfall, which is important to understand the relationship between rainfall and landslide events.

Figure 11 shows the major rainfall-triggered incidents in Nepal in 2020. Out of the total 488 landslides reported in the year 2020, 59 occurred along roadsides and 62 occurred on roads, in all cases obstructing vehicular flow (GoN, 2020b). On July 7 of the same year, the Besisahar-Chame road, which links Manang and Lamjung, was blocked for about 12 hours due to a landslide that occurred at Khudi of the Marsyangadi Municipality, Lamjung (RSS, 2020). Similarly, a landslide at Charkilo obstructed the Naranyanghat-Muglin road and halted traffic on September 11 (RSS, 2020). Furthermore, a landslide occurred in a newly widened road, taking the lives of nine people in the Waling Municipality, Syangja (Shrestha, 2020). The BIPAD/DRR portal also showed that landslides in 2020 obstructed traffic in multiple sections of the Prithvi Arniko, Siddhartha, Jayprithvi and B.P highways. Additionally, the Beni-Jomson, Kathmandu-Hetauda, and Beni-Maladhung roads were disrupted at several locations, adversely affecting transport services. The country's media reported that it was the haphazard construction of roads and the disregard of geological conditions and natural drainage that had led to the landslides along roads (GoN, 2020b).

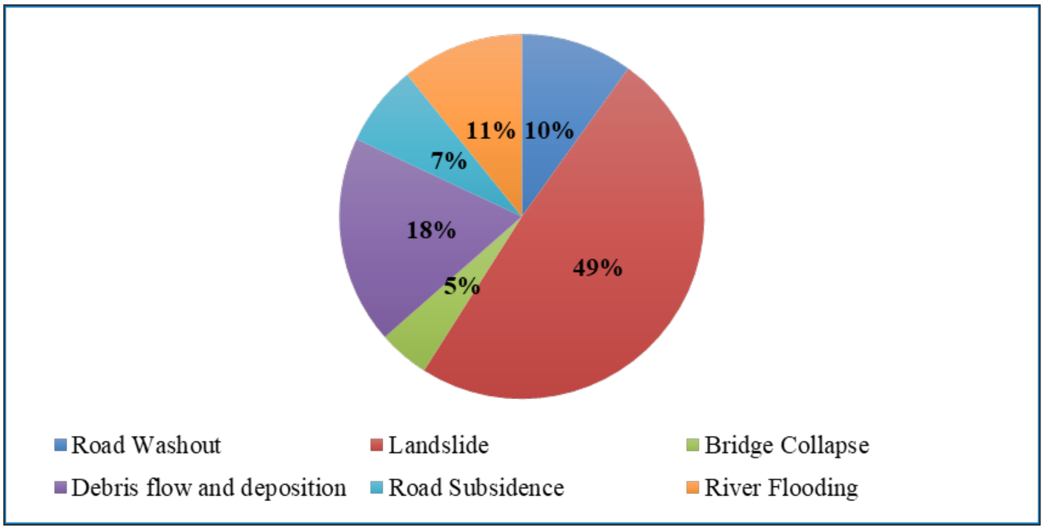


Figure 11: Rainfall triggered the incident in the roadside area (July 9 –Aug 27, 2020)

In the Terai region, the increase in the temperature intensifies the instances of cracks on roads, while heavy precipitation leads to potholes. The poor road conditions resulting from such natural calamities increase the chances of accidents and delay the transportation of necessities to the rural communities. An increase in the consumption of fuel and related costs is another consequence of the traffic jams caused due to damaged roads.

4.2 Economic Impacts

ITPI-related infrastructure and services are critical to economic development and social movement at the local, regional, national, and international levels. They enable the distribution of goods and services within and between countries and provide easy access to schools, markets, and health services. However, the ITPI worldwide has been undergoing massive stresses due to disasters related to climate change.

Over the last three decades, the per capita GDP from Nepal's ITPI has increased from USD 180 in 1980 to USD 762 in 2015. In addition, the population below the poverty line has dropped to 25.16%. The country's road network, which was virtually non-existent in 1950, has now increased to around 80,000 km in total. However, the Strategic Road Network (SRN) is only 13,447.62 km (see Figure 12) and two district headquarters (Humla and Dolpa) are yet to be connected to the road network (DoR, 2018). Although domestic airlines operate more than 30,000 flights a year, connecting remote areas of the hills and mountains to the rest of the country, this service is limited to a fraction of the population and those who can afford it.

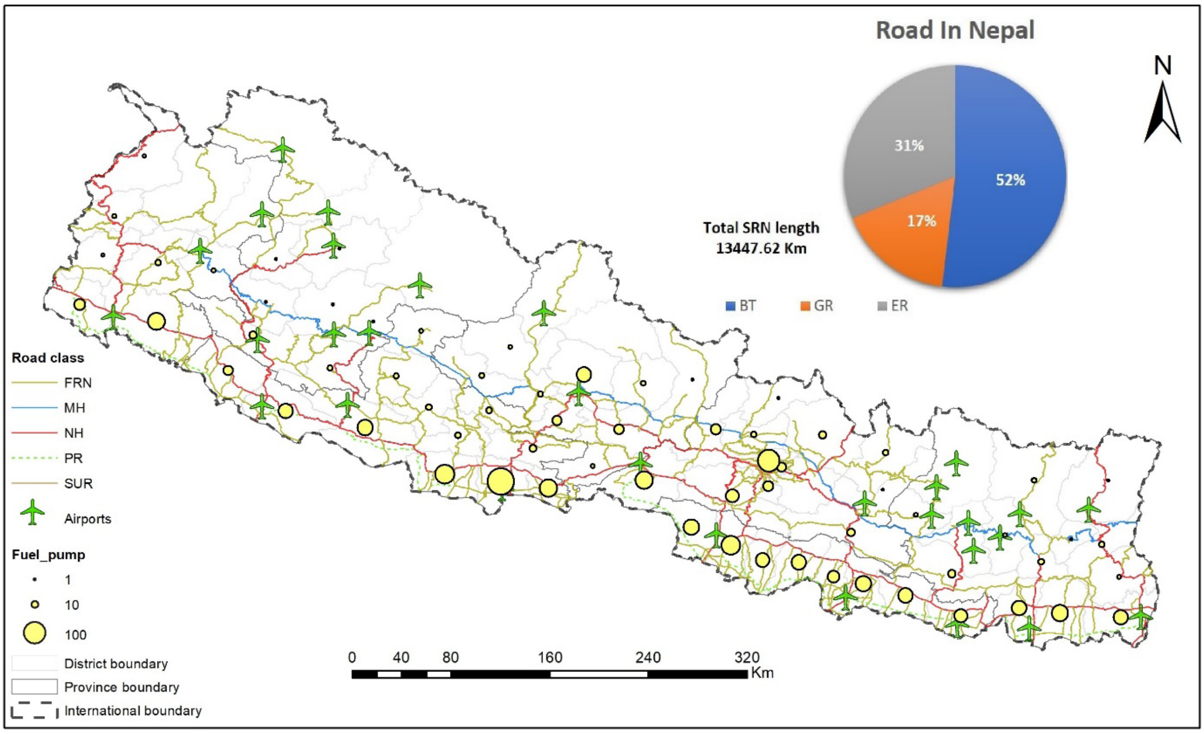


Figure 12: Strategic Road Network in Nepal

During the monsoon season, roads are highly impacted due to landslides triggered by rains and constant toe cutting by flooding rivers. Related impacts consist of high costs for maintenance and repair; limited community access to jobs, schools, and hospitals; and large economic losses. This is also evident in the trends of climate-induced disaster events and economic loss in Nepal. These trends show a steep increment of disasters from 1970 to 2019 (see Figures 13 &14). Especially, landslide and flood events have increased more than other disasters compared to previous years, resulting in greater economic losses in the ITPI in the years that follow.

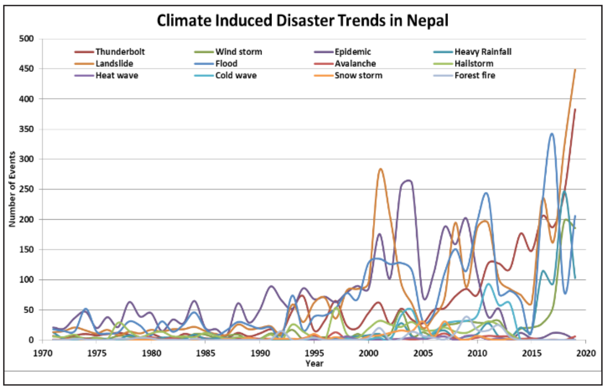


Figure 13: Climate-induced disaster trends in Nepal

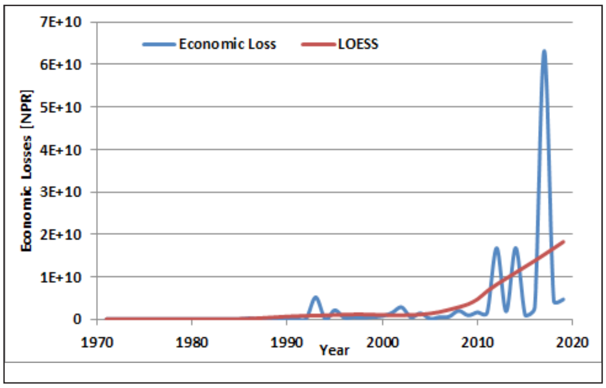


Figure 14: Economic and life loss during extreme events

In Nepal, industrial production is estimated to be increasing by 12.4% annually (CIA, 2018). However, the economic impact of climate change is estimated to be equivalent to an annual cost of 1.5 to 2% of GDP currently and is expected to rise to 2 to 3% of current GDP per year by mid-century (IDS, 2014). In 2017, physical damages worth USD 584.7 million occurred due to rainfall-triggered disasters in the country (NPC, 2017). Climate change's significant impact can also be seen in the annual budget allocation for periodic road maintenance costs, which have increased from 1.19 billion to 3 billion between FY 2016/17 and FY 2019/2020 (see Table 4).

Table 4: Annual budget allocation for SRN repair and maintenance

S.N.	Fiscal year	Annual allocation for SRN maintenance	Annual allocation for periodic maintenance
1	2016/17	3.7 billion	1.19 billion
2	2017/18	3.09 billons	0.70 billion
3	2018/19	3.80 billion	0.91 billion
4	2019/2020	6.05 billion	3.00 billion

The rapid increase in the length of rural roads in the last 30 years in Nepal corresponds to an increase in investment in the Local Road Network. Until 2007/2008, investment in rural roads was increasing at a uniform rate. Then, in 2008/2009 BS, the budget for rural roads increased by almost 1.9 times the budget for 2007/2008. This increase could be linked to the end of the Maoist rebellion. The rise in the budget over the next few years, particularly dramatic in 2015/2016, could be linked to the promulgation of the 2015 Constitution as well as to the Gorkha earthquake. The budget allocated in 2017/2018 was 7.5 times the budget of 2007/2008. After 2015/2016, the budget began to be allocated as per the new public financing mechanism under the federal governance structure.

Today, investments in the LRN are spread across the federal, provincial, and local levels, and almost 60-70% of the total road budget is spent on the LRN each fiscal year[1]. The LRN is financed through the government's budget as well as through development partners. It is widely perceived that the role of development partners is in the construction of new LRN roads whereas the role of the government is to fund the maintenance of existing roads, as shown in Figure 15.

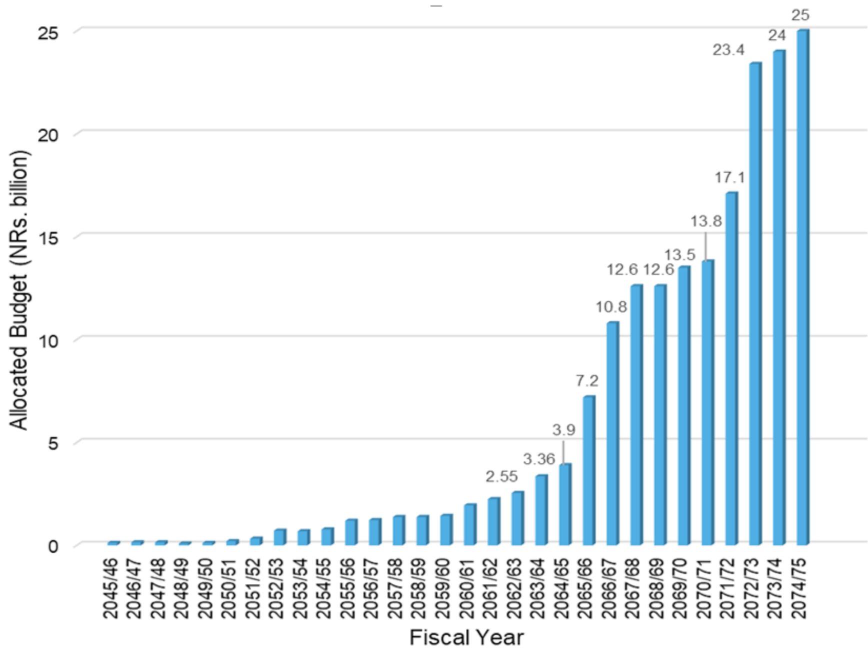


Figure 15: Allocated budget in LRN (last 30 years)

1 Consultation at DoLI

That said, the current practice of building roads does not use a precautionary approach. Instead, the preference is for building faster without following basic norms or standards, using inappropriate techniques, and cutting corners in costs. Current practices seem to disregard specific hazard contexts and the risks present in Nepal's mid-hills.

4.3 Socio-demographic impacts

Climate change has the potential to impact Nepal's population as well as its social, cultural, and natural resources in various ways. In the industrial sector, climate change impacts add stress to employment and disturb the supply chain and livelihood. For the majority of individuals working in the informal economy and small enterprises, it is especially difficult to recover from the effects of environmental disasters (ILO, 2009, 2017d; IPCC, 2014). Additionally, in the case of Nepal, there are around 355403 small cottage industries, which is much higher than the number of industries registered in the Department of Industry (DoI, 2020b). Furthermore, climate change impacts, together with the exclusion of women from adaptation and mitigation actions, worsen the obstacles and socio-economic vulnerabilities and prevent women from getting decent employment opportunities. (Nellemann et al., 2011).

Transportation systems are critical for effective disaster response—for example, when populations have to be evacuated before an approaching storm or where the provision of food, water, and emergency services is urgently needed for affected populations. Disturbance in transportation can lead to reduced access to health, education, and agricultural extension services, while disturbance in industrial operations has a direct impact on the livelihoods of people (Shrestha, 2007). Additionally, rural transport is used for fetching water, agricultural inputs, and fuel-wood collection, which are the types of roles usually undertaken by women in Nepal. Women in rural households undertake different transportation tasks and often carry a heavier burden in terms of time and effort in transporting materials (Blackden & Wodon, 2006). Overall, climate change related risks and hazards threaten the aforementioned vital lifelines.

Climate Stressors and Livelihood Havoc

"Rising temperatures, heatwaves, cold waves, floods and inundation have taken a toll on our region. These issues have directly impacted our assets and livelihoods. Extreme weather events such as heatwaves and extreme precipitation have put not only our physical assets but also our lives at risk. 'No job, no pay', such disastrous events have obliged us to fight for our existence. Industries meet our daily needs and unforeseen natural hazards have made our workdays in industries challenging."
– Local consultation, Gadi Rural Municipality, Province 1

Chapter 5

Observed and Projected Climate Change Hazards and Exposures in the ITPI

5.1 Climate trends and scenarios of Nepal

A. Changes in precipitation and extreme wet days

Both extreme weather variability and climate change have an impact on the industry, transport, and physical infrastructure sectors. Extreme weather events, particularly during the monsoon season in Nepal, create problems. Normally, the summer monsoon lasts for 105 days. In 2020, however, it lasted for 130 days, which was 25 days more than normal. According to the DHM (2020), the daily accumulated rainfall during the 2020 monsoon (June-September) was higher than normal (determined by the average of observed rainfall amounts between 1981 and 2010) in eastern Nepal but less than normal in western Nepal.

Figure 16 below shows the mean positive and negative annual trends for extremely wet days and precipitation. The districts with values between 0 and 0.1 represent extreme wet days. The district of Syangja showed a positive trend compared to other districts, meaning that it is likely that the district will experience another extreme rainy day every consecutive 10-year period. 29 districts experienced increasing annual rainfall and 48 districts showed a decreasing trend. The annual precipitation trends showed a significant downward trend for Kaski (-11.44 mm/yr) and a significant upward trend for Syangja (9.0 mm/yr).

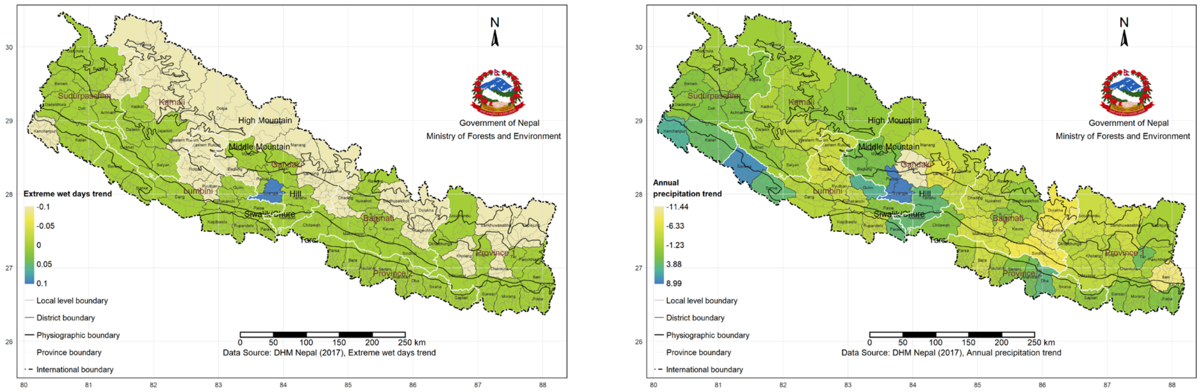


Figure 16: (a) Extreme wet days trend, (b) Annual precipitation trend

The shifts in weather patterns might also cause significant disruptions in transport, infrastructure, and the daily operation of industries. Changes in precipitation patterns could have an impact on road safety as accidents become more frequent. Similarly, extreme precipitation could also lead to traffic congestion, inundation of roads and collapse of infrastructure, increasing operational and maintenance costs (Koetse & Rietveld, 2009). In addition, several analysts have attempted to examine the relationship between rainfall thresholds and landslide initiation. Dahal and Hasegawa (2008) collated data related to 677 landslides that occurred in Nepal from 1951 to 2006, then compared the rainfall data from 193 of these landslide events to yield a threshold relationship between rainfall intensity, rainfall duration, and landslide initiation. They found that when daily precipitation exceeds 144 mm, the risk of landslides on mountain slopes is high and that a steep landscape saturated by antecedent rainfall is susceptible to landslides even with a small amount of intense rainfall. These facts illuminated the temporal and spatial character of rainfall, which is important to understand the relationship between rainfall and landslide events. The national daily thresholds currently used as warning levels for landslide initiation are shown in Table 6 below.

Table 5 Rainfall threshold for landslide initiation in slopes

Amount (mm)	Period (hours)
140	24
120	12
100	6
80	3
60	1

Source: Department of Hydrology and Meteorology

B. Changes in temperature

Nepal's maximum temperature trend was found to be significantly positive, showing an increased rate of 0.056^{0}C/yr (DHM, 2017). The Manang and Taplejung districts had steeper increasing trends of annual maximum temperature, i.e., 0.092^{0}C/yr and 0.091^{0}C/yr respectively (see Figure 17). In contrast, the Bara and Rautahat districts showed the least positive (increasing) trends. Gradual shifts in long term temperature trends might have reduced the productive capacity of Nepal's industrial sector due to their direct effects on infrastructure. These trends not only directly impact the lifespan of infrastructures but also affect the effectiveness of services that these infrastructures provide. As such, these trends of change in maximum temperature might directly influence the gradual increment of possible future risks in Nepal's ITPI.

The magnitude of positive trends is larger in the mountain districts than the districts in lower elevations. This pattern is evident in all seasons (e.g., the highest trend of 0.12°C/yr is observed in Manang in winter) but is more evident in the monsoon season (DHM, 2017). Furthermore, out of the five physiographic regions, Terai has the lowest positive trend (0.036 °C /yr) and the high Himalayas have the highest positive trend (0.072°C/yr) (DHM, 2017). The IPCC AR-4 designated the Hindukush-Himalaya region a "white spot" to climate change.

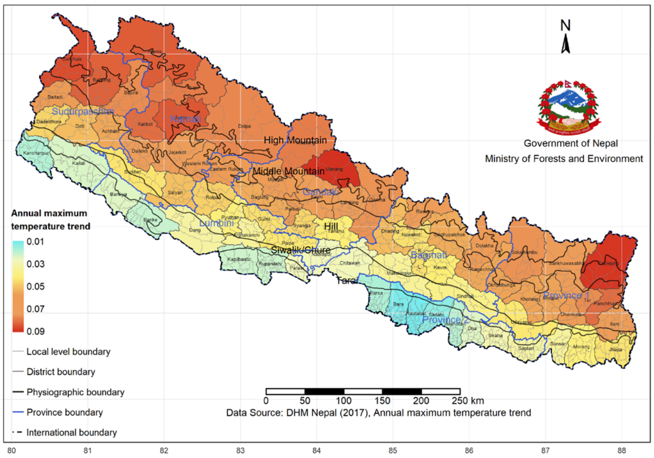


Figure 17: Annual maximum temperature trend

The glacial lake inventory has identified 25 out of 2,070 lakes that are considered potentially dangerous glacial lakes. Table 6 shows the past incidences of GLOF events, alongside various degrees of socioeconomic impacts on livelihoods, transport, and hydropower industries. As many of the roads in Nepal lie alongside riverbank and the energy sector is dependent on run-off water, these types of events can increase the susceptibility of the ITPI to catastrophic consequences.

Table 6: Magnitude and downstream impact of GLOFs in the past

Name of Glacial Lake	Date of Outburst	Downstream impact
Nare, Dudhkoshi	Sept. 3, 1977	• Flood surge down to 90 km • Loss of life and infrastructures (3 persons, 1 building, 10 bridges) down to 35 km
Nagama (Phucan), Tamor basin	June 23, 1980	• Eroded riverbed down to 23 km • Loss of life and infrastructure (8 people, 10 houses, 4 bridges) down to 72 km
Zhangzanbo, Bhotekoshi/ Sunkoshii	July 11, 1981	• Flood surge down to 50 km (16 times larger than the average annual floods) • Vertical erosion down to 6 km; lateral erosion between 6-20 km; lateral erosion and deposition between 20-50 km • Major damages between 20-55 km (5 persons killed, 191 injured; damage to 84 houses, 2 highway bridges, 10 suspension bridges, 27 km road, 1 hydro dam, 1 km transmission line) • Power supply cut for 31 days; road blocked for 36 days • Road rehabilitation cost US$ 3 million; work lasted for 3 years
Dig Cho, Dudhkoshi	August 4, 1985	• The alternation between erosion and accumulation activities down to 42 km; most of the eroded materials redeposited within the first 25 km • Loss of life and infrastructure (4-5 persons, 30 houses, 14 bridges, 1 hydropower plant, 8 km of trails, 20 ha cultivated land) down to 40 km • Economic loss amounting to USD 4 million

Source: Modified (CFGORRP, 2014)

A snapshot of the report "Climate Change Scenario of Nepal, 2019"

Changes in precipitation and temperature

- Average annual precipitation is likely to increase by 2–6% in the medium term period and by 8–12% in the long term period.
- Average annual mean temperature is likely to rise. Mean temperature could increase by 0.9–1.1 ^{0}C in the medium term period and 1.3–1.8 ^{0}C in the long term period
- Both the average annual mean temperature and the average annual precipitation are projected to increase until the end of the century. Precipitation could increase by 11–23%, and mean temperature might increase by 1.7–3.6 ^{0}C by 2100.
- The average temperature is projected to increase for all seasons. The highest rates of mean temperature increase are expected for the post-monsoon season (1.3–1.4 ^{0}C in the medium term period, and 1.8–2.4 ^{0}C in the long term period) and the winter season (1.0–1.2 ^{0}C in the medium term period, and 1.5–2.0 ^{0}C in the long term period).

Changes related to climate extremes in future periods

- Intense precipitation events are likely to increase in frequency, with extremely wet days (P99) expected to increase at a higher rate than very wet days (P95).
- The number of rainy days is likely to decrease in the future. This, in combination with the increase in precipitation intensity, is likely to create more water-related hazards in the future.
- Future changes in consecutive dry days (CDD) and consecutive wet days (CWD) vary with different RCP scenarios. The RCP 4.5 scenario projects a likely increase in CDD, while the extreme scenario RCP 8.5 projects a likely decrease. In congruence with this trend, CWD is projected to decrease under the RCP 4.5 scenario and is likely to increase under RC P8.5.
- Both warm days and warm nights are likely to increase in the future. The number of warm days will rise sharply, from 36 days to 60 days a year in the medium term, and to 68 days a year in the long term period, under the RCP 4.5 scenario. This is in congruence with increasing temperature trends in the future.
- Both cold days and cold nights are likely to decrease in the future. The number of cold days declined by 42–53% under the RCP 4.5 scenario over the two periods in this study. This too is in concurrence with increasing temperature trends.
- The durations of warm spells, of at least six days of high maximum temperatures, are likely to increase sharply in the future under both RCP 4.5 and RCP 8.5 scenarios. This is in conjunction with increasing temperature trends and increasing warm days of the future periods.

Source: MoFE & ICIMOD, 2019

5.2 Climate change hazards in the ITPI and sub-sectors

Trend analyses and future projections of climate change hazards can highlight not only the impact of climatic hazards but also how these impacts change over time. Usually, emphasis is placed on stressors or extreme events of a certain magnitude, frequency, and potential for immediate impact. For example, it is well established that changes in the magnitude and frequency of extreme rainy days can lead to floods and landslides that directly affect road infrastructure and industrial operations (GIZ & EURAC, 2017). However, depending on the geologic structures involved and their sensitivity to climate variability, different districts may experience different impacts from similar extreme events. In this assessment, key climate extreme events were identified and assigned weightage based on literature reviews, and consultation with stakeholders at the national, provincial, and local levels.

Table 7: Climate extreme events in the ITPI

Climate Extreme Events	Expert weightage	Supporting Literatures
Change in precipitation	0.2	• IPCC AR-5, working group III (2014) • IPCC AR-4, Impacts, Adaptation and Vulnerabilities (2007) • Climate Change Adaptation in Industrial Area (GIZ, 2018) • Climate Resilient Planning (NPC, 2011) • The Potential Impacts of Climate Change on Transport (TRBNRC, 2008) • Economic Impact Assessment of Climate Change (IDS, 2014) • Development and Climate Change in Nepal (OECD, 2003) • Climate Change Challenges and Solutions in Infrastructure Planning and (ILF, 2018) • UNCRD, 2015
Change in warm days (%)	0.15	
Change in cold spell duration (%)	0.15	
Change in temperature (0C)	0.1	
Change in warm spell duration (%)	0.1	
Change in extreme wet days (%)	0.1	
Change in consecutive dry days (%)	0.1	
Change in consecutive wet days (%)	0.1	

The district-wise average trends of the above-identified climate change stressors (see Table 7) are discussed in this chapter. These trends are derived from climate-related data from 1971 to 2014 provided by the Department of Hydrology and Meteorology (DHM, 2020).

5.2.1 Baseline and future projection of climate extreme events in ITPI

Transport infrastructure and industrial operations are vulnerable to both temperature and precipitation events. Extreme wet days, changes in precipitation, changes in consecutive wet days (CWDs), and changes in temperature were the key climate extreme events identified in this assessment. Baseline examination showed that the Kapilbastu, Rupadehi, Parasi, Arghakanchi, Gulmi, and Palpa districts in Lumbini Province; the Parbat, Syangja, Tanahu, and Nawalpur districts in Gandaki Province; the Chitwan and Makwanpur districts in Bagmati Province; the Parsa and Bara districts in Province 2; and the Sankhuwasabha, Morang, Ilam, and Jhapa districts in Province 1 experience a high level of climate extreme events (see Figure 18). Paved roads are particularly vulnerable to extreme temperatures, while unpaved roads and bridges are vulnerable to precipitation extremes. Table 7 shows the major climate extreme events that are associated with precipitation. This can be linked to the high probability of occurrence of different climate extreme events such as floods, landslides, inundations, et cetera. The extreme 24-hour rainfall in Nepal is usually associated with floods in the Terai region and small to large scale mass wasting in the Chure/Siwalik, middle mountain, and high mountain regions (GoN, 2014a). In line with the baseline patterns observed in the districts that are mostly situated in the middle-hill, hilly, Siwalik/Chure, and Terai regions, precipitation-related stressors were also assigned high weightage in the ITPI sector consultations.

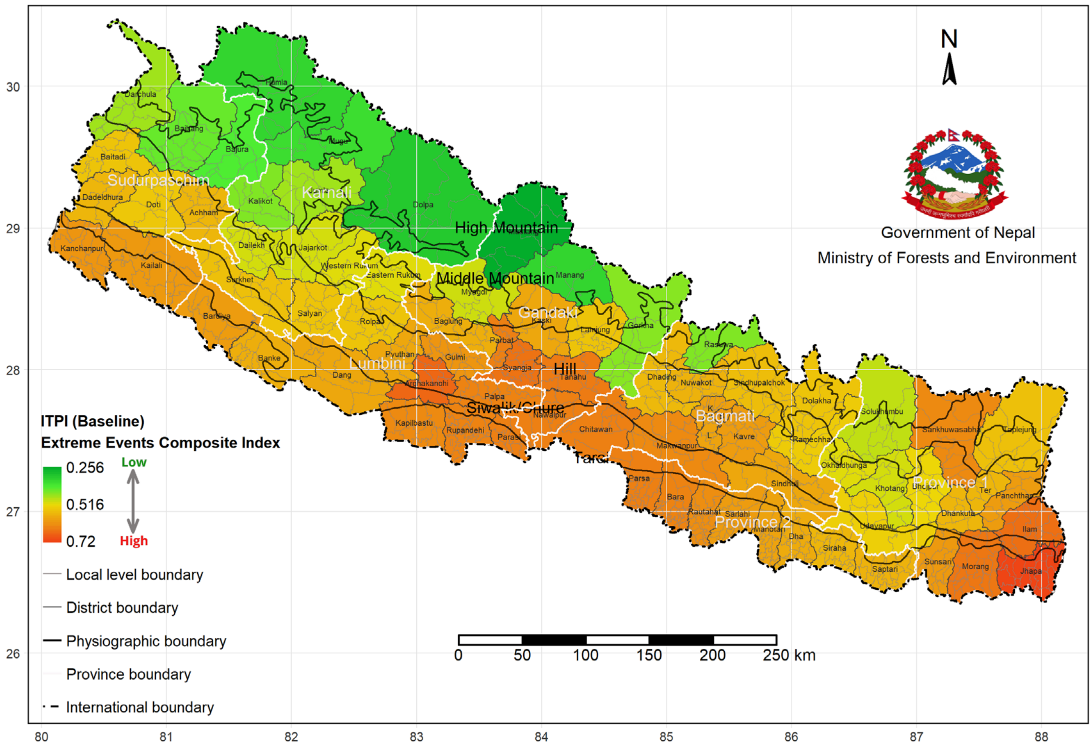
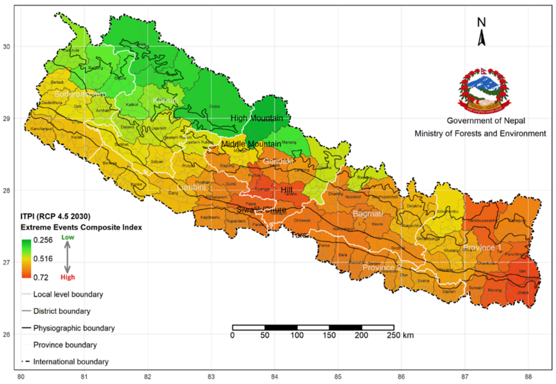


Figure 18: Composite ranking of climate extreme events

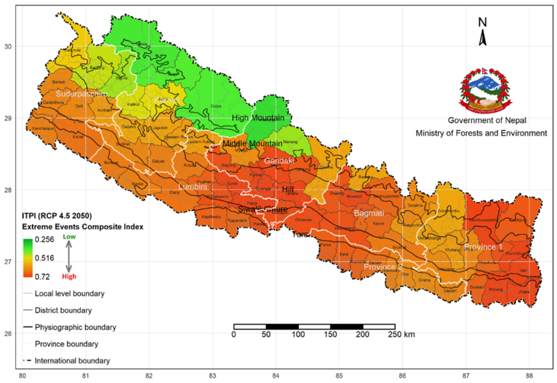
5.2.2 Future scenarios of climate extreme events in ITPI

The climate extreme events relevant to the ITPI sector are expected to increase in the future. Figure 19 (parts a and b) shows the projected changes in the average annual mean of combined climate change stressors for the medium term (2030s) and the long term (2050s) under RCP 4.5, compared to the reference period (1981-2010). In the medium term, Province 1 appears likely to experience a greater increase in climate extreme events, compared to other provinces. Whereas in the long term, the highest likelihood of an increase in climate extreme events appears to be in Province 1, followed by the Bagmati, Gandaki, Lumbini, and Sudurpaschim Provinces.

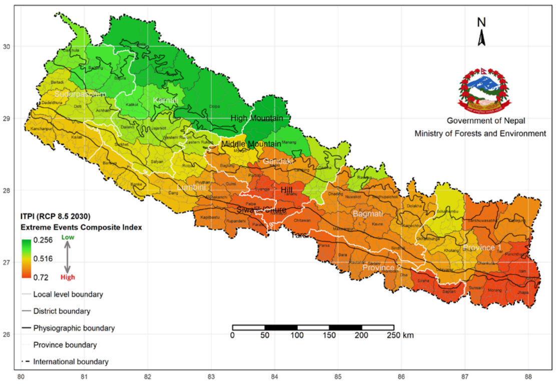
The rest of Figure 19 (parts c and d) shows the projected changes under RCP 8.5 in the medium (2030) and long (2050) terms. In the medium term, the average level of climate extreme events is projected to be high in Province 1, followed by Province 2 and the Gandaki, Bagmati, and Lumbini Provinces. In the long term, the change in climate extreme events is projected to affect all provinces. As per these projections, all the districts in Province 1 and Province 2 appear likely to experience a high level of climate extreme events under RCP 8.5. Districts in the Gandaki, Lumbini, Karnali, and Sudurpaschim Provinces are projected to have a high level of extreme events only in the long term under RCP 8.5. The average change in climate extreme events in the upper districts of Karnali Province and Sudurpaschim Province is projected to have a low value in the medium and long terms under RCP 4.5 and only in the medium term under RCP 8.5. In addition, only two districts (Humla and Dolpa) in Karnali Province and one district (Mustang) in Gandaki Provinces is expected to experience a low level of climate extreme events in the long term under RCP 8.5



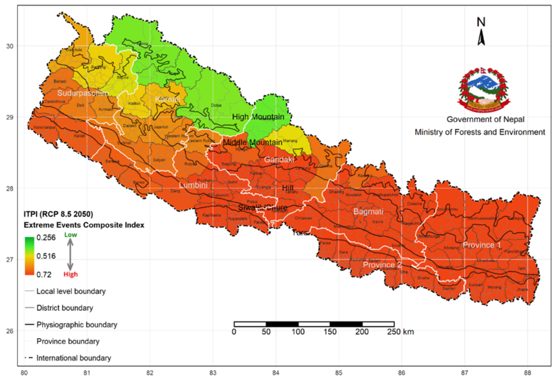
(a) RCP4.5-2030



(b) RCP4.5-2050



(c) RCP 8.5-2030



(d) RCP 8.5-2050

Figure 19: Projected climate change stressors

5.3 Climate change exposures in the ITPI

Exposure indicators used in this report for the transport sector include the number of vehicles in operation; length of the strategic roads; and the number of airports in operation. For the industrial sector, the number of industries in operation and dependent population (number of employees) were included as indicators. Based on these indicators, the ITPI can be assessed in terms of infrastructures (capacity), services, and networks (coverage). Capacity represents the space available for the establishment of industries and transport infrastructure. The number of passengers and the supply of the food chain can be linked to services, and connectivity can be linked to coverage. Districts with minimal infrastructure, services, and networks determine the exposure limits of the sector. Transport and industry are demand-driven sectors and need proportionate development irrespective of geography. However, the current exposure ranks show an unequal distribution pattern of development.

Stakeholder consultations were conducted in all seven provinces. During these, it was pointed out the occurrence of heavy rainfalls often cause flash flooding in the rivers. This flooding, in turn, causes damage to bridges, highway blockages, and stuck vehicles, which prevent vehicles from transporting fuels, emergency supplies, and raw materials. In the past, such impacts have caused major losses in livelihoods and the economy. Compared to others, districts like Chitwan and Kathmandu are very highly exposed because of their population density and relatedly higher concentration of transport, industries, and infrastructures. In line with the notion that the higher the exposure, the higher the possibility of climate risk (Global Climate Risk Index, 2021), these districts also had the highest amounts of the following: length of SRN, number of registered vehicles, number of industries, and number of employees (see Figure 20 and Table 8).

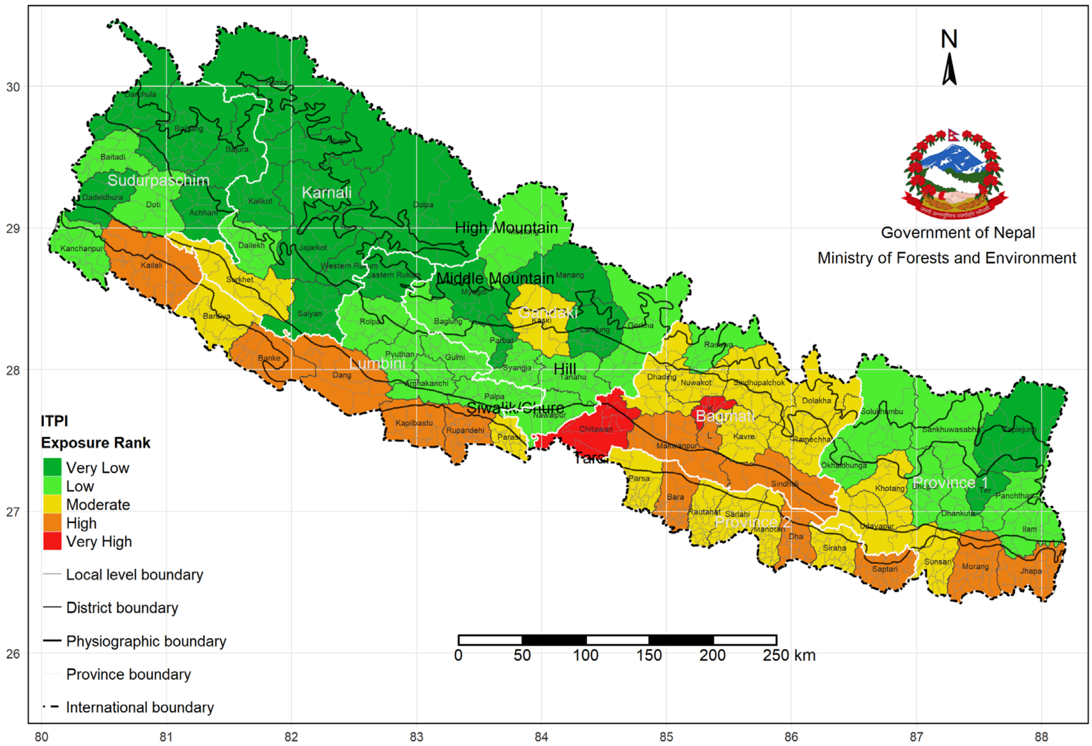


Figure 20: Climate change exposure rank map of ITPI sector

Besides the aforementioned two highly exposed districts, the majority of high-exposure districts were observed to be in the Terai region. These districts have a higher population concentration and relatedly higher quantum of transport, industries, and physical infrastructures, exposing them to impacts from multiple climate hazards such as floods, droughts, heatwaves, cold waves, epidemics, et cetera. In contrast, it was found that the Karnali and Sudurpaschim Provinces—more specifically their middle and high mountain regions—have low to very low exposure, as they lack adequate transport and infrastructure facilities because of their geographical features. However, this situation might change in the future as the cut-off districts within these provinces are a priority for the government to link up with the rest of Nepal.

Table 8: Comparison of adjoining districts with high and low exposure

District	Context	Reason
Bara, Dhanusha and Parsa	High: Bara and Dhanusha Moderate: Parsa	Province 2: Bara and Dhanusha has have 190 & 251km of SRN, 39 and 36 numbers of strategic bridges respectively and 1 domestic airport in operation, which are higher than Parsa.
Kathmandu, Chitwan, Bhaktapur and Rasuwa	Very high: Kathmandu and Chitwan Moderate: Bhaktapur Low: Rasuwa	Bagmati Province: Kathmandu and Chitwan have 250 km & 233 km SRN, 57422 & 12664 number of industries, 244279 & 14724 employees working in different industries respectively, in comparison to Bhaktapur and Rasuwa. Kathmandu and Chitwan have airports in operation whereas the other two districts lack them.
Banke, Bardiya and Dang	High: Banke and Dang Moderate: Bardiya	Lumbini Province: Banke and Dang have 365 & 226 km SRN, 1 domestic airport in each, and 7198 & 6509 number of industries respectively whereas, Bardiya has 219 km SRN and 6301 industries.
Dadeldhura and Kailali	High: Kailali Very low: Dadeldhura	Sudhurpaschim Province: Kailali has 359 km SRN, 100 strategic bridges, and 7810 industries, which are much higher than in Dadeldhura.

According to the consultations, the movement of vulnerable populations into risky areas is in part because such areas have relatively low monetary value and can thus be purchased or rented at low costs. Establishing settlements, even on landslide-prone roadsides, is a strategy inhabitants adopt to diversify their livelihood options. They feel that this strategy will enable them to become better equipped to handle the other risks that they face, such as crop failure. Thus, more and more people opt to live in roadside-prone settlements despite safety concerns. Further, the exact reasons behind why adjacent districts have a different level of exposure are outlined in Table 8.

Table 9: Exposure rankings for different districts

Exposure Rank	District
Very high (0.713 - 1)	Chitwan, Kathmandu
High (0.486 - 0.712)	Makawanpur, Kapilbastu, Lalitpur, Banke, Kailali, Rupandehi, Sindhuli, Morang, Bara, Dhanusha, Dang, Jhapa, Saptari
Moderate (0.316 - 0.485)	Dhading, Sunsari, Dolakha, Nuwakot, Rautahat, Sindhupalchok, Bardiya, Kavrepalanchok, Udayapur, Bhaktapur, Surkhet, Siraha, Khotang, Kaski, Sarlahi, Mahottari, Parasi, Parsa, Ramechhap
Low (0.189 - 0.315)	Rolpa, Rasuwa, Dhankuta, Sankhuwasabha, Baglung, Gorkha, Solukhumbu, Tanahu, Dailekh, Pyuthan, Syangja, Arghakhanchi, Baitadi, Palpa, Bhojpur, Mustang, Doti, Okhaldhunga, Nawalpur, Kanchanpur, Panchthar, Gulmi, Ilam
Very low (0.070 - 0.188)	Humla, Mugu, Myagdi, Lamjung, Terhathum, Western Rukum, Parbat, Darchula, Dolpa, Achham, Salyan, Manang, Eastern Rukum, Bajura, Kalikot, Taplejung, Jajarkot, Jumla, Bajhang, Dadeldhura

Climate Change Vulnerability and Risks in the Sector

6.1 Sensitivity

The sensitivity of the ITPI is shaped by the natural and/or physical attributes of the system. It includes the topography, different soil types, and land cover types which affects the physical constitution, such as tillage, water management, resource depletion, and population pressure.

The major indicators for sensitivity include proximity to hazard, traffic flow, population density, types and scale of industry, condition of roads, condition of bridges, and types of the airport (paved/non-paved). Additional indicators include GDP contribution from the industrial sector, number of female employees in the industry, airports in different geographic regions, the proximity of roads and bridges to floods and landslides, and earthen roads.

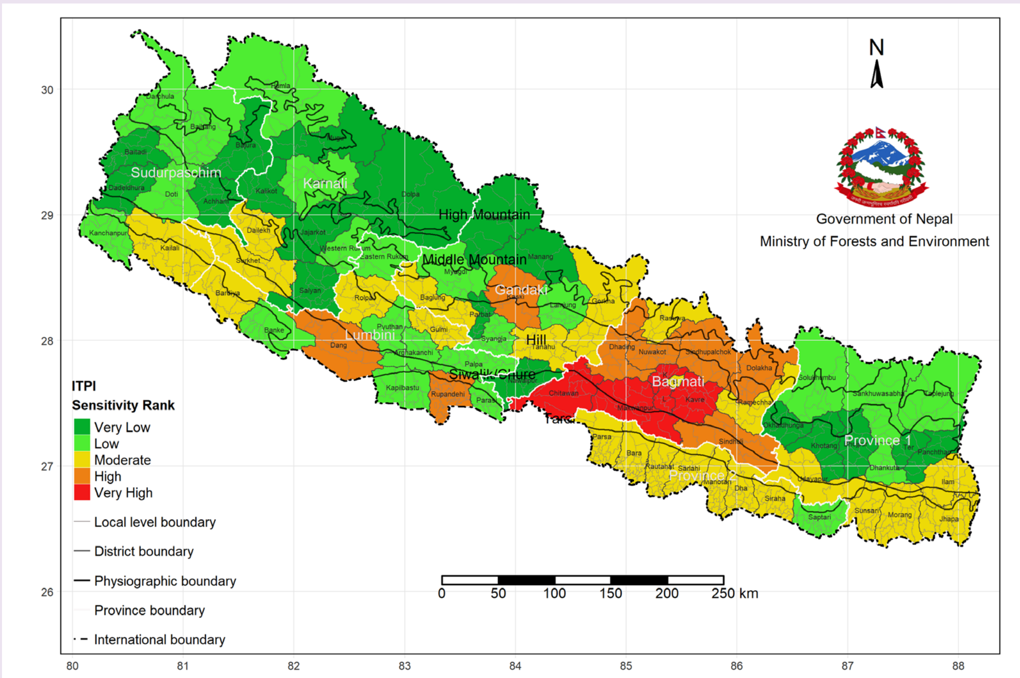


Figure 21: Sensitivity rank map of the ITPI sector

Figure 21 and Table 11 show the sensitivity indicator ranks of different districts. Five districts—Chitwan, Makwanpur, Kavrepalanchok, Kathmandu, and Lalitpur—were found to have very high sensitivity. In contrast, 18 districts were found to have a very low sensitivity rank. It is interesting to note that even though these districts lie in the same physiographic region or province, their sensitivity ranks differ from each other. Factors that contribute to these differences are traffic flow and congestion, percentage of population influenced by disaster per kilometer road, number of vehicles in use that are above 20 years, the proximity of roads to landslides and floods, economic capability (GDP contribution), types of industry, and number of female employees in the industry (for examples, please see Table 10).

Table 10: Comparison of high and low sensitivity ranks among adjoining districts

District name	Context	Reason
Kathmandu, Lalitpur and Bhaktpur	Very high: Kathmandu and Lalitpur Moderate: Bhaktapur	Bagmati Province: Kathmandu and Lalitpur districts have higher annual average daily traffic (809163 & 399862), populations influenced per km road (6971 & 3460), earthen road (20 and 32), road length with more than 300 slope angle (30 and 14 km) and road in a flood-prone area (250 and 135 km) in compare to adjoining district Bhaktapur.
Kaski, Manang and Tanahu	High: Kaski Tanahu: Moderate Very Low: Manang	Gandaki Province: Kaski and Tanahu districts have high annual average daily traffic 22818 &13919), populations influenced per km road (3155 & 1801), earthen strategic road network (58 & 51 km), a road in landslide-prone area (155 & 165 km) and the number of female employees (12101 & 1536) in compare to adjoining district Manang.
Rupandehi, Dang and Kapilbastu	High: Rupandehi and Dang Low: Kapilbastu	Lumbini Province: Rupandehi and Dang districts have high annual average daily traffic (116618 & 48402), road length with more than 300 of slope angle (53 & 17 km), number of agriculture and forest-related industries (1079 & 2350), and number of female employees (8133 & 2174) in comparison to the district Kapilbastu.

In addition, the above figure is also validated by the views of officials from the Ministry of Home and Affairs, who said, "the hilly districts of Nepal located in the Siwalik, Mahabharat range, mid-lands and fore, and higher Himalayas are more susceptible to landslides because of their steep topography and fragile ecosystems".

Table 11: Sensitivity rankings of different districts

Sensitivity Rank	District
Very high (0.855 - 1)	Makawanpur, Lalitpur, Kavrepalanchok, Chitwan, Kathmandu
High (0.741 - 0.854)	Dhading, Dolakha, Nuwakot, Sindhupalchok, Rupandehi, Sindhuli, Dang, Kaski
Moderate (0.649 - 0.740)	Rolpa, Rasuwa, Sunsari, Rautahat, Baglung, Bardiya, Gorkha, Tanahu, Dailekh, Udayapur, Bhaktapur, Kailali, Surkhet, Siraha, Morang, Bara, Dhanusha, Jhapa, Sarlahi, Mahottari, Parsa, Gulmi, Ramechhap, Ilam
Low (0.577 - 0.648)	Humla, Kapilbastu, Myagdi, Lamjung, Dhankuta, Sankhuwasabha, Western Rukum, Solukhumbu, Pyuthan, Darchula, Syangja, Banke, Arghakhanchi, Palpa, Doti, Eastern Rukum, Kanchanpur, Taplejung, Jumla, Parasi, Bajhang, Saptari
Very low (0.493 - 0.576)	Mugu, Terhathum, Parbat, Dolpa, Achham, Baitadi, Bhojpur, Salyan, Mustang, Manang, Khotang, Okhaldhunga, Bajura, Nawalpur, Kalikot, Panchthar, Jajarkot, Dadeldhura

6.2 Adaptive capacity of the ITPI

Adaptive capacity is assessed by analysing the capability of a given system for responding to climate change impacts. Adaptive capacity indicators include national policies, standards, guidelines, e-mobility plans and policies, efficient traffic management, GESI-friendly policy endorsement, fuel compliance and standards, flight holdings, proper parking management at the airport, insurance and/or employees of industries, and emission reduction schemes that help respond to climate change impacts. According to the analysis conducted for this study, 11 districts—namely Kailali, Dang, Rupahdehi, Kaski, Chitwan, Makwanpur, Kathmandu, Lalitpur, Bara, Morang, and Jhapa—were found to have the very high adaptive capacity (see Figure 22 and Table 10). The districts ranked with very high and high adaptive capacity had features such as long length of blacktopped SRN, high quality of the road, high numbers of weather-related information sharing stations, good accessibility of and to domestic and international airports, and availability of skilled manpower in industries.

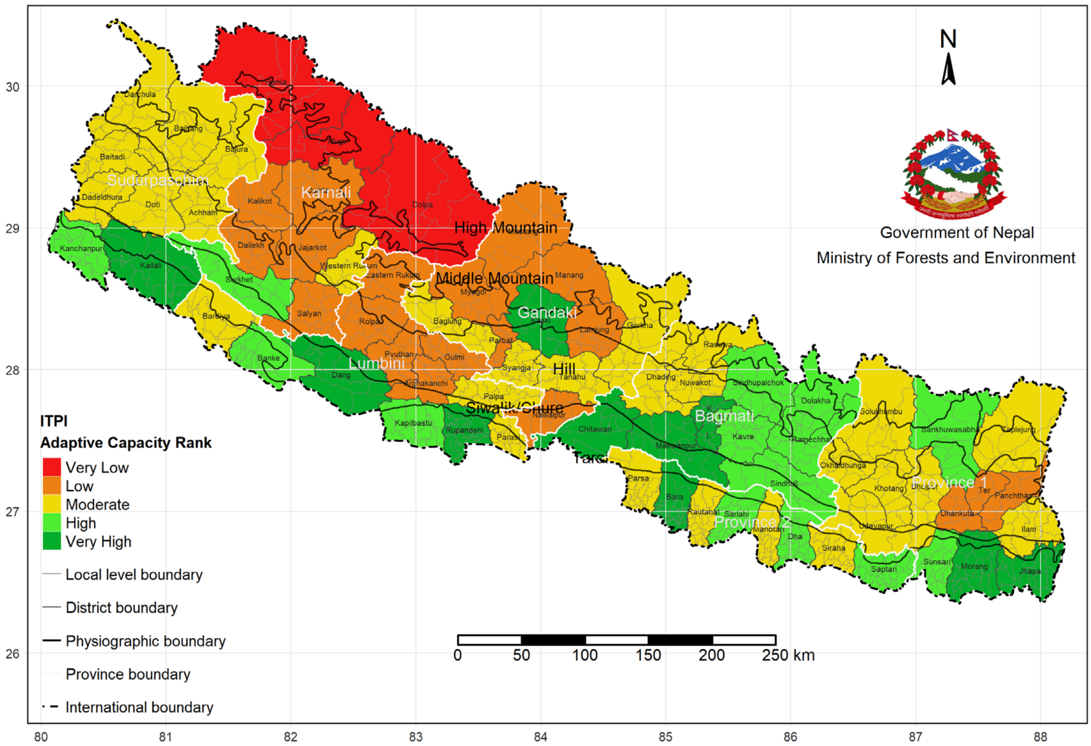


Figure 22: Adaptive capacity rank map of the ITPI

Table 12: Comparison of districts with different adaptive capacity ranks

District name	Context	Reason
Terhathum, Dhankuta and Sankhuwasabha	High: Sankhuwasabha Low: Terhathum and Dhankuta	Sankhuwasabha has a higher length of blacktopped SRN (92 km) than Terhathum (33 km) and Dhankuta (80 km). The number of weather-related information sharing stations is high in Dhankuta (7) followed by Sankhuwasabha (5) and Terhathum (1). Similarly, the domestic airport is only operated in Sankhuwasabha, as a result of which it exhibits a high level of adaptive capacity.
Bara, Parsa and Rautahat	Very high: Bara Moderate: Parsa and Rautahat	Bara has a higher length of blacktopped SRN (109 km) than Rautahat (72 km) and Parsa (29 km). The number of weather-related information sharing stations is high in Bara (7), compared to Parsa (1) and Rautahat (2). Further, 1 domestic airport is in operation in Bara.
Kathmandu and Nuwakot	Very high: Chitwan Moderate: Nuwakot	Provision of the green sticker (vehicular emission) is enforced in Kathmandu but not mandatory outside of Kathmandu valley. Blacktopped SRN in Kathmandu (222 km) is higher than Nuwakot (133). The quality of roads is much better in Kathmandu than in Nuwakot. Similarly, the availability of skilled manpower in the small cottage industry is very high in Kathmandu (7605) than in Nuwakot (0).

District name	Context	Reason
Kaski and Manang	Very high: Kaski Low: Manang	Kaski has a higher length of blacktopped SRN (92 km) than Manang (0) and the quality of its roads is better in Kaski. Skilled manpower availability in the small and cottage industries is very high in Kaski, compared to Manang.
Arghakhanchi and Kapilbastu	High: Kapilbastu Low: Arghakhanchi	The length of blacktopped SRN is high in Kapilbastu (187 km) than in Arghakhanchi (62 km). Road quality is better in Kapilbastu than in Arghakhanchi. Skill manpower availability in the small and cottage industries is very high in Kapilbastu (6251) than in Arghakhanchi.
Kailali and Doti	Very high: Kailali Moderate: Doti	The length of blacktopped SRN is high in Kailali (239 km) than in Doti (116 km). The quality of roads and number of retention walls are better in Kaillai than in Doti

Districts that mainly lie in the Terai region were ranked as having very high to high adaptive capacity, followed by the districts with a metropolitan city, such as Kathmandu, Lalitpur, Chitwan, Kaski, and Morang. These high rankings were due to the following: structural robustness, employee insurance schemes, skilled manpower in industry, proper river discharge estimation, sharing of the blacktopped road, public-private partnerships, and social security schemes. In contrast, it was the absence of these features that contributed to the low adaptive capacity ranking of the Humla, Dolpa, and Mugu districts in Karnali Province and the Doti and Bajhang districts in Sudurpaschim Province.

A high level of adaptive capacity has the potential to make the transport and industrial sectors more resilient. For example, even though the urban flood that occurred in Bhaktapur on 12th July 2018 caused significant economic loss and disturbance in road traffic, the quickness of the response to it helped the city recover in a relatively short period. In contrast, the Jure landslides of Sindhupalchok on 2nd August 2014, caused enormous economic loss and damage to infrastructures due to the locality's limitations in coping and adaptation strategies.

Table 13: Adaptive capacity ranks of different districts

Adaptive Capacity Rank	District
Very high (0.690 - 1)	Makawanpur, Lalitpur, Kailali, Rupandehi, Morang, Bara, Chitwan, Dang, Kaski, Jhapa, Kathmandu
High (0.579 - 0.689)	Kapilbastu, Sunsari, Dolakha, Sankhuwasabha, Sindhupalchok, Kavrepalanchok, Bhaktapur, Banke, Surkhet, Sindhuli, Dhanusha, Kanchanpur, Sarlahi, Ramechhap, Saptari
Moderate (0.488 - 0.578)	Dhading, Rasuwa, Nuwakot, Rautahat, Baglung, Western Rukum, Bardiya, Gorkha, Solukhumbu, Tanahu, Udayapur, Darchula, Syangja, Achham, Siraha, Baitadi, Palpa, Bhojpur, Doti, Khotang, Okhaldhunga, Bajura, Taplejung, Mahottari, Parasi, Bajhang, Parsa, Dadeldhura, Ilam
Low (0.331 - 0.487)	Rolpa, Myagdi, Lamjung, Dhankuta, Terhathum, Dailekh, Parbat, Pyuthan, Arghakhanchi, Salyan, Mustang, Manang, Eastern Rukum, Nawalpur, Kalikot, Panchthar, Jajarkot, Jumla, Gulmi
Very low (0.224 - 0.330)	Humla, Mugu, Dolpa

6.3 Vulnerability in the ITPI

Vulnerability in this report is defined as a "function of the character, magnitude, and rate of climate variation to which a system [ITPI] is exposed, its sensitivity, and its adaptive capacity." Vulnerability rankings differ between districts based on the condition and types of physical and institutional infrastructure, their proximity to hazards, and the number of livelihood opportunities that depend on them. The vulnerability of the ITPI has a direct influence on its economic stability and day-to-day services. Provincial consultations revealed that in general industrial operations and transportation infrastructure are highly susceptible to extreme events, such as landslides, floods, temperature changes, and precipitation. It was also noted that heavy rains often disturbed road traffic and air services, such as during the flood at the Biratnagar Airport in 2019. The ITPI is expected to be affected by climate change variables in several ways. Temperature changes—both a gradual increase in temperature and an increase in extreme temperatures—are likely to impact road pavements through, for example, heat-induced heaving and buckling of joints. Additionally, extreme weather events, such as stronger and/or more frequent storms, are likely to affect the capacity of drainage and overflow systems to deal with stronger or faster velocity of water flows.

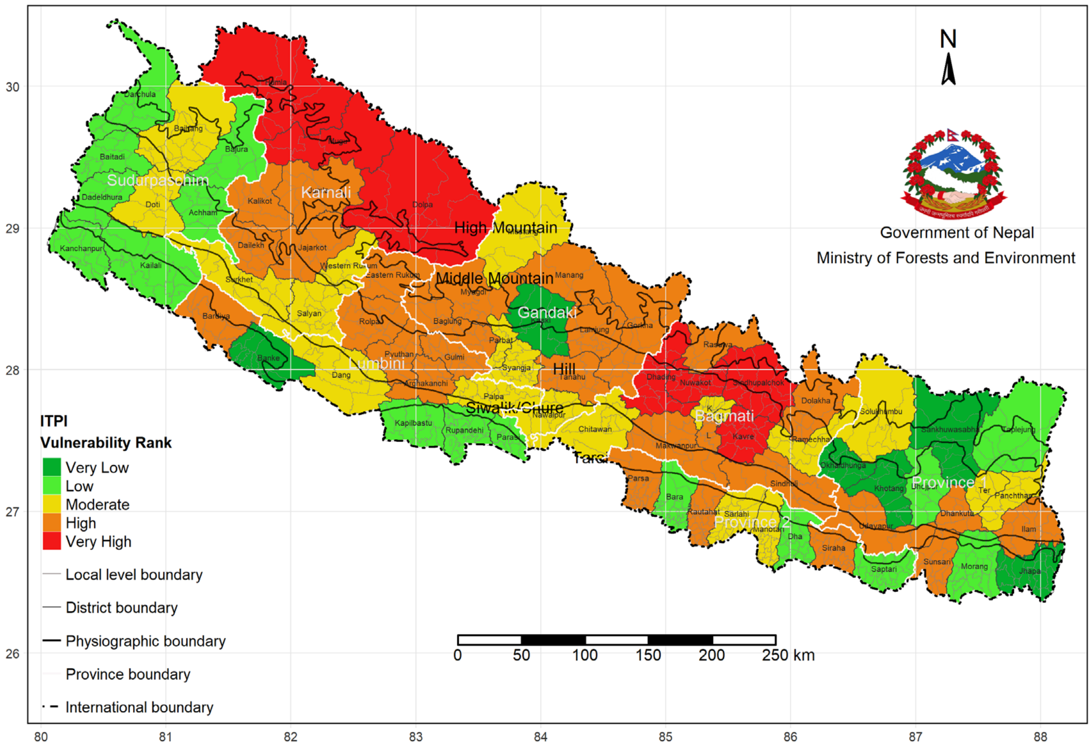


Figure 23: Vulnerability map of Nepal

In Nepal, the majority of the SRN is located along riverbanks or in low-lying areas, putting its economic capital and populations at risk from climate-related hazards such as flood events, GLOFs, landslides, and debris flow from torrential rainfalls. Infrastructure damage, disruptions in service-providing sectors, shortages of goods, and frequent use of emergency health services place a socioeconomic burden on urban and rural livelihoods. These challenges are interrelated. For example, economic losses make it difficult for residents to maintain their livelihoods and can therefore exacerbate social issues including poverty. The aforementioned findings show how vulnerability rankings of districts differ according to the relative levels of their sensitivity and adaptive capacity.

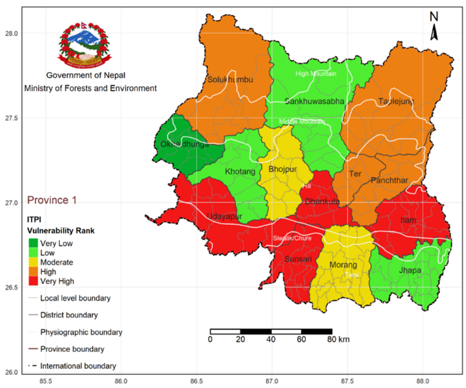
Seven districts—namely Dhading, Humla, Mugu, Dolpa, Nuwakot, Sindhupalchok, and Kavrepalanchok—were ranked as very highly vulnerable and 28 districts as highly vulnerable (for more details, see Figure 23 and Table 14). These districts lie in the high mountain, middle mountain, and hilly regions. In contrast, most districts in the Terai region were ranked as having low to very low vulnerability, mainly because they are less sensitive to climate change impacts due to better quality of roads and bridges and availability of skilled manpower in the industrial sector. However, some of the districts in the Terai region do fall under the medium to high vulnerability ranking as well.

Table 14: Vulnerability ranks of different districts

Vulnerability Rank	District
Very high (0.682 - 1)	Dhading, Humla, Mugu, Nuwakot, Sindhupalchok, Kavrepalanchok, Dolpa
High (0.514 - 0.681)	Rolpa, Makawanpur, Rasuwa, Myagdi, Lamjung, Sunsari, Dolakha, Dhankuta, Rautahat, Baglung, Bardiya, Gorkha, Lalitpur, Tanahu, Dailekh, Udayapur, Pyuthan, Siraha, Arghakhanchi, Sindhuli, Manang, Eastern Rukum, Kalikot, Jajarkot, Jumla, Parsa, Gulmi, Ilam
Moderate (0.355 - 0.513)	Terhathum, Western Rukum, Solukhumbu, Bhaktapur, Parbat, Syangja, Surkhet, Palpa, Salyan, Mustang, Doti, Chitwan, Dang, Nawalpur, Panchthar, Sarlahi, Mahottari, Bajhang, Ramechhap, Kathmandu
Low (0.231 - 0.354)	Kapilbastu, Darchula, Kailali, Achham, Baitadi, Rupandehi, Bhojpur, Morang, Bara, Dhanusha, Bajura, Kanchanpur, Taplejung, Parasi, Saptari, Dadeldhura
Very low (0.076 - 0.230)	Sankhuwasabha, Banke, Khotang, Okhaldhunga, Kaski, Jhapa

The province-wise analysis revealed that in Province 1, the Dhankuta, Illam, Udayapur, and Sunsari districts were very highly vulnerable districts. This was due to their high sensitivity that resulted from factors such as annual average daily traffic, types and quality of roads, level of road inclination, the proportion of female employment in industry, and GDP contribution from the industrial sector. Additionally, Dhankuta also had a very low level of adaptive capacity. In contrast, the district of Okhaldhunga was ranked in the very low vulnerability category, mainly due to its infrastructure and resources.

The Parsa and Rautahat districts in Province 2 were ranked in the very high vulnerability category, whereas, the rest of the province's districts were ranked as having a mixed level of vulnerability. What contributed to the very high vulnerability ranking of Rautahat and Parsa were the low adaptive capacity ranking of the former and the very high sensitivity ranking of the latter. Their vulnerability ranking was further informed by sensitivity indicators such as the number of manufacturing, construction, and agriculture- and forest-based industries, the proportion of GDP contribution, types of road, and annual levels of traffic flow.



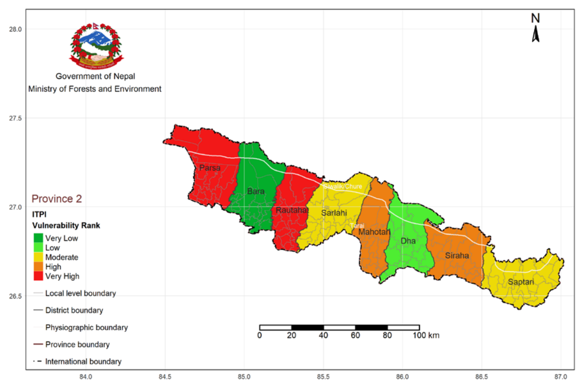


Figure 24: Vulnerability maps of Province 1 and Province 2

In Bagmati Province, the Dhading, Nuwakot, and Kavrepalanchok districts were ranked in the very high vulnerability category, while Kathmandu, Bhaktapur, and Ramechhap were ranked in the very low vulnerability category. Differences in the levels of vulnerability were related to differences in 'green sticker' regulations, size of strategic road network being blacktopped, quality of existing roads, and several skilled manpower in small cottage industry. In Gandaki Province, the Lamjung, Tanahu, and Gorkha districts were ranked in the very high vulnerability category, whereas Myagdi and Baglung were ranked in the high vulnerability category. In contrast, Kaski was ranked as having very low vulnerability due to its higher level of adaptive capacity resulting from factors such as road quality, skilled manpower availability in the industry, and airport facilities (see Figure 25).

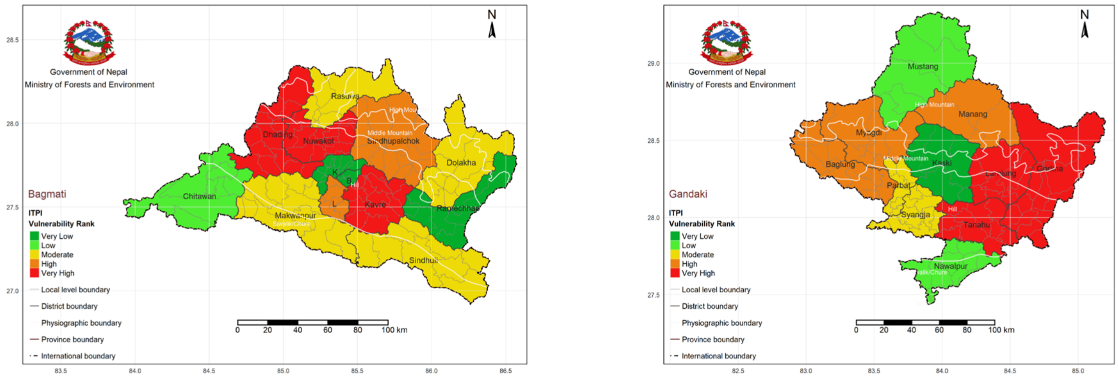


Figure 25: Vulnerability map of Bagmati Province and Gandaki Province

In Lumbini Province, the Eastern Rukum, Rolpa, Piyuthan, and Gulmi districts were ranked in very high vulnerability category, whereas Bardiya, Dang, and Arghakhachi were ranked in a high vulnerability category (see Figure 26). Sensitivity indicators like kilometers of earthen road, the inclination of the road more than 30⁰ (40 to 60), and types and scale of industries played a key role in determining the differences in vulnerability ranks among districts. Similarly, the topography, especially the proximity of physical infrastructure to landsides, also played a vital role in increasing the vulnerability rank of some districts like Rolpa, Pyuthan, and Gulmi. In Karnali Province, Humla and Mugu were ranked very high in terms of vulnerability, whereas Dailekh and Dolpa ranked high. However, at the national level, the Humla, Mugu, and Dolpa districts were ranked as having very high vulnerability (see Figure 26).

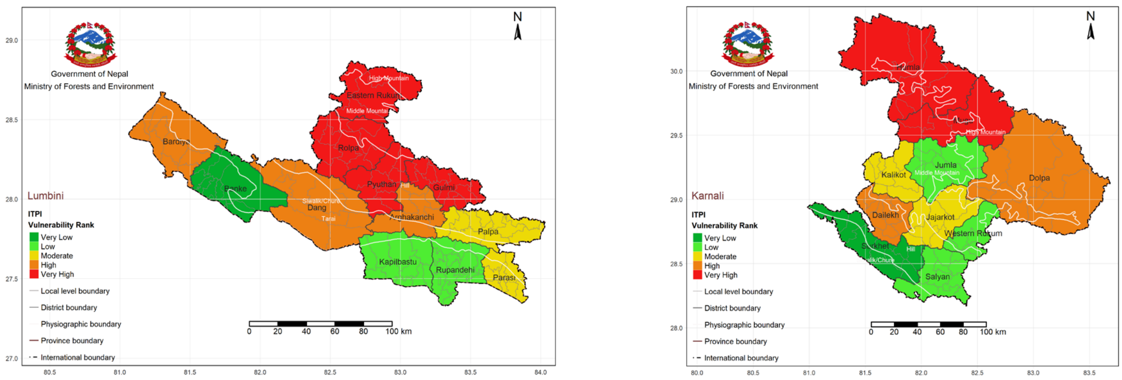


Figure 26: Vulnerability Map of Lumbini and Karnali Province

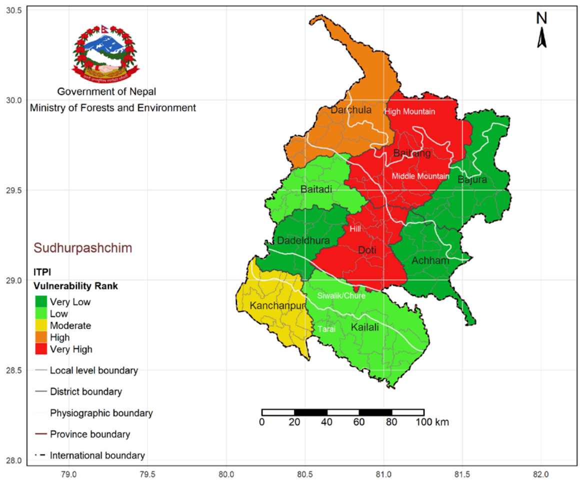


Figure 27: Vulnerability Map of Sudurpaschim Province

In Sudurpaschim Province, the Bajhang and Doti districts were ranked as being very highly vulnerable, whereas Darchula fell under the highly vulnerable category (see Figure 27). But in a nationwide (rather than province-wide) comparison of districts, these three districts fell under moderate and low vulnerability categories. In general, the provinces of Karnali and Sudurpaschim have high sensitivity and very low adaptive capacities, making their districts highly vulnerable to climate change. For example, the connectivity of roads in the upper belt of Karnali Province is very poor, whereas the quality of roads is poor in high-mountain and the middle-mountain regions of Sudurpaschim. Similarly, features and conditions related to the proximity of current road infrastructure to landslides, geographical structures, air transport facilities, and social security schemes in the upper belt of Karnali and Sudurpaschim Provinces make them more vulnerable. The vulnerability levels of different physiographic regions are presented in Annex 11. However, it should be noted that the vulnerability rankings soon, particularly in the next 10 years, might change significantly as there is expected to be more road and infrastructure development in Nepal's provinces.

6.4 Risks from climate change impacts in the ITPI

6.4.1 Baseline of climate change risk in the sector

The IPCC AR-5 report (2014) already predicts that risks from extreme events will continue to rise as the global average temperature rises. Considering that Nepal's annual average maximum temperature also follows an upward trend, associated risks would be even greater in the future. The long-term climate risk index, which shows that Nepal was one of the top ten countries affected by climate change between 1999 and 2018, also confirms this. Rising risk indicates a certain level of exposure and hence vulnerability to extreme events.

Consultations at the federal, provincial, and local levels revealed that future climate change impacts are expected to pose additional challenges. Stakeholders agreed that if the design and standards of the transportation sector and industry are not revised, there are likely to be huge economic losses in the future. Consultation with stakeholders in Bagmati Province revealed that the construction of a road without proper direction hugely raises the risk of extreme impacts from rainfall-triggered disasters. In Province 2, stakeholders said that they felt that floods and inundation have become more frequent events and have a direct impact on industrial production and supply.

Figure 28 below highlights the climate-induced risk in the ITPI at the baseline level (i.e., current situation). In these sectors, risk assessment is applied to the different modes of transportation for physical, technical, financial, and civil protection. The Dhading, Makawanpur, Nuwakot, Sindhupalchok, Lalitpur, Kavrepalanchok, Sindhuli, Chitwan, Parsa, and Kathmandu districts appeared to have a very high risk, whereas Sunsari, Dolakha, Rautahat, Bardiya, Tanahu, Udayapur, Kailali, Siraha, Rupandehi, Dang, Sarlahi, Mahottari, and Saptari were ranked as having high risk (see Figure 28 and Table 15). The districts under the very high risk category are mainly in Bagmati Province, whereas the districts with low to very low risk rankings are in Karnali, Sudurpaschim (except Kailali), and Gandaki Provinces (except Tanahu). These differences in levels of risk were informed by exposure indicators like the length of SRN, number of strategic bridges, number of industries, and number of employees in the industrial sector. Similarly, the key climate change stressors in these sectors, like change in precipitation, change in extreme wet days, change in consecutive wet days, and temperature change, played are a significant role in determining the risk rankings of different districts.

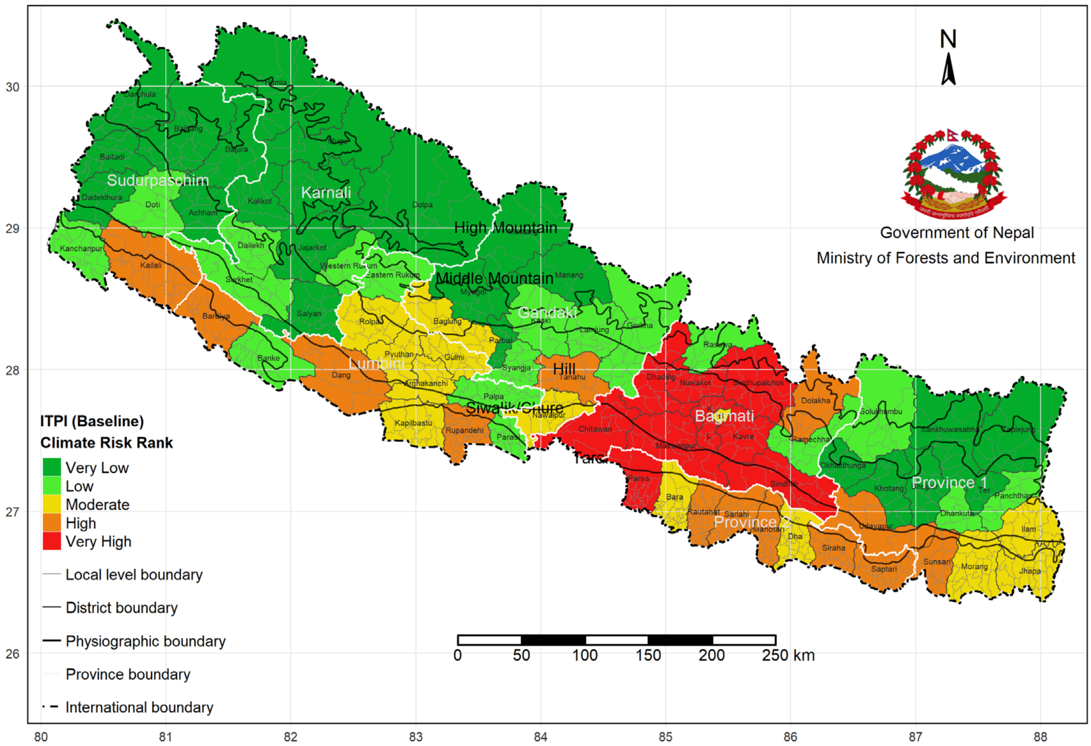


Figure 28: Baseline of climate risk in the ITPI sector

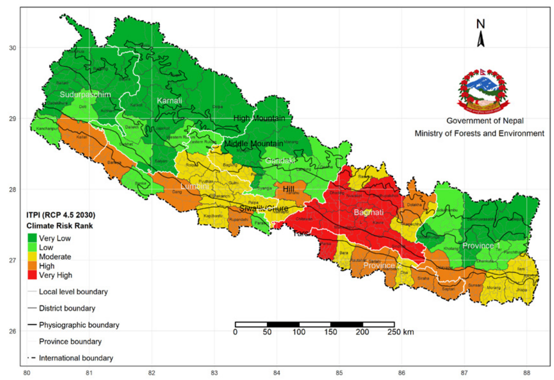
Table 15: Overall baseline climate risk rank in ITPI

Baseline Climate Risk Rank	Districts
Very high (0.477 - 0.720)	Dhading, Makawanpur, Nuwakot, Sindhupalchok, Lalitpur, Kavrepalanchok, Sindhuli, Chitawan, Parsa, Kathmandu
High (0.314 - 0.476)	Sunsari, Dolakha, Rautahat, Bardiya, Tanahu, Udayapur, Kailali, Siraha, Rupandehi, Dang, Sarlahi, Mahottari, Saptari
Moderate (0.220 - 0.313)	Rolpa, Kapilbastu, Baglung, Bhaktapur, Pyuthan, Arghakhanchi, Morang, Bara, Dhanusha, Nawalpur, Jhapa, Gulmi, Ilam
Low (0.116 - 0.219)	Rasuwa, Lamjung, Dhankuta, Western Rukum, Gorkha, Solukhumbu, Dailekh, Syangja, Banke, Surkhet, Palpa, Doti, Eastern Rukum, Kaski, Kanchanpur, Panchthar, Parasi, Ramechhap
Very low (0.032 - 0.115)	Humla, Mugu, Myagdi, Terhathum, Sankhuwasabha, Parbat, Darchula, Dolpa, Achham, Baitadi, Bhojpur, Salyan, Mustang, Manang, Khotang, Okhaldhunga, Bajura, Kalikot, Taplejung, Jajarkot, Jumla, Bajhang, Dadeldhura

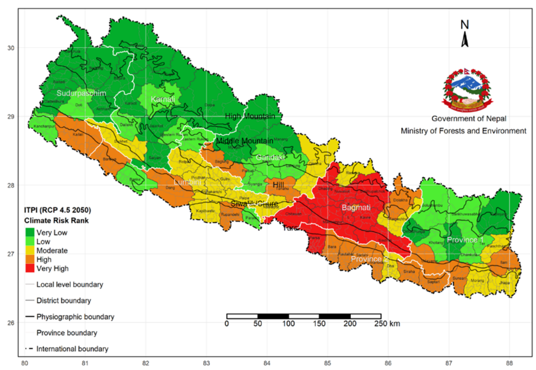
6.4.2 Risk scenarios in ITPI

Figure 29 shows the projected risk in the ITPI for both medium term and long term scenarios. The first two figures, (a) and (b), show the change in risk levels in the ITPI for RCP 4.5 in the medium and long terms. The medium term showed very high and high risk levels, mostly in Bagmati Province (except in the districts of Bhaktapur, Rasuwa, and Ramechhap). In the long term period, districts in Lumbini Province and Province 1 also came under high risk. The main reason for this is the likely increase in climate extreme events such as upward changes in temperature and precipitation, increase in warm days, and increase in extreme wet days.

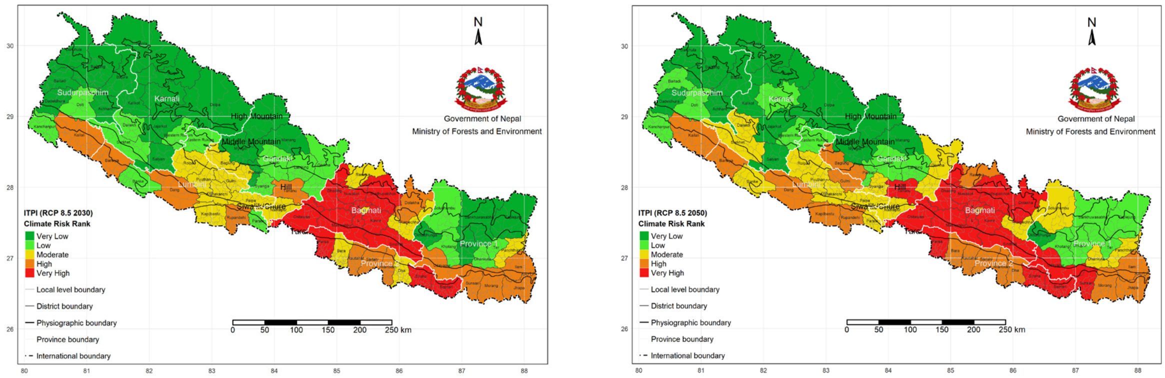
The other two figures, (c) and (d), show the projected risk for RCP 8.5 in the medium and long term scenarios. In the medium term, the overall risk scenario observed is similar to RCP 4.5 (2030), where most of the districts fell in very high and high risk ranks in Bagmati Province (except for Bhaktapur, Rasuwa, and Ramechhap). Province 2 and Province 1 fell under the high risk category. In the long term period of RCP 8.5, more districts (except Ramechhap) in Bagmati Province fell in very high and high ranks. Besides, in Province 2, three districts fell in the very high risk rank, while the remaining five districts got high risk. Lumbini Province is expected to have a high to moderate level of projected risk. However, in all four projection models, risk levels were observed to be comparatively low in most of the districts in Karnali Province and Sudurpaschim Province. In terms of physiographic regions, the risk level was observed to be comparatively very high in the hill, Siwalik/Chure and Terai regions followed middle-hill and high-mountain districts.



(a) RCP 4.5 - 2030



(b) RCP 4.5 - 2050



(c) RCP 8.5 - 2030 (d) RCP 8.5 - 2050

Figure 29: Risk scenarios in ITPI

The overall trends show that future climate change will aggravate the risk from climate change impacts in the ITPI. At the baseline, ten districts were in the very high risk category, but in the long term for RCP 8.5 (2050), 16 districts were projected to come under the very high risk category. Table 16 below shows that only 15 districts in RCP 8.5 (2050) will have low risks from climate change impacts in the ITPI.

Table 16: Number of districts with different risk scenarios under RCP 4.5 and 8.5 for 2030 and 2050

Risk Ranks	Baseline (Current)	RCP 4.5 (2030)	RCP 4.5 (2050)	RCP 8.5 (2030)	RCP 8.5 (2050)
Very high	10	10	10	12	16
High	13	13	17	14	17
Moderate	13	16	15	14	15
Low	18	17	17	16	14
Very low	23	21	18	21	15
Total	77	77	77	77	77

The IPCC confirmed that if the present climate change trends persist, high temperatures and humidity would probably compromise outdoor working by the middle of the century. As large sections of the population are dependent on the ITPI, climate change conditions leading to lost work capacity and reduced labour productivity among vulnerable populations will eventually cause huge economic losses. The percentage of working hours lost to heat stress in Nepal is 1.17% currently, which is projected to increase to 2.05% by 2030 (ILO, 2019). Similarly, future levels of risk in the transportation sector will be much higher as a result of Nepal's current development trajectory. The construction of local and rural roads in mountain and hill areas often neglects the adoption of safeguarding norms, which is likely to result in increased hazards and risks from climate change impacts. The physiographic risk scenarios are presented generated in this study are presented in Annex 10.

Chapter 7

Adaptation Options in the Sector

Adaptation is the process of adjustment to actual or expected climate and its effects. It involves reducing risk and vulnerability; seeking opportunities; and building the capacity of nations, regions, cities, the private sector, communities, individuals, and natural systems to cope with climate impacts, as well as mobilizing that capacity by implementing decisions and actions. Adaptation options are the array of strategies and measures available and appropriate to address needs. (Tompkins et al., 2010). Identifying possible adaptation options can enable physical and institutional infrastructures (like transport, communication, and supply systems) to move information, goods, and people, particularly during emergencies, and inform the preparedness of the ITPI to deal with potential risks in the future.

To make the process of identifying adaptation options more participatory and inclusive, consultations with stakeholders at the provincial and local levels were organized. Furthermore, past and present applied adaptation practices were also examined to consider how best to deal with the impacts of climate change in the ITPI. To make adaptation options more relevant to present and future contexts, short-term (1-5 years), medium term (10 years), and long term (30 years) actions were envisioned as presented in Table 14 below.

Table 17: Adaptation options for the ITPI

Risks and vulnerabilities	Adaptation Options		
	Short term (1-5 years)	Medium term (1-10 years)	Long term (30 years)
The industry sector			
The loss and damage due to climate-induced disasters, costing small and medium enterprises highly Key risks to the well-being of women and male workers who are exposed to heat and cold stresses	• Promote health and safety measures in every industry to ensure the protection of laborers exposed to climate extreme events such as heatwaves, cold waves, hot days, and cold days • Identify industrial areas vulnerable to the risks of climate disasters and prepare hazard maps for all geographical areas • Promote circular economy and industrial ecology concepts to improve resilience and sustainability in the industrial sector • Implement Corporate Social Responsibility (CSR) principles effectively to attract private sector investment in energy efficiency schemes and climate change adaptation measures	• Make a provision for mandatory inclusion of climate risk management in all industries during the design and planning phase • Adopt risk transfer and insurance mechanisms covering i) every employee/ labor in the industrial sector, ii) small and medium size enterprises • Develop a system for timely issuing of short-term weather forecasts and regular climate bulletin and/or information flow mechanism • Adopt the Resource Efficient and Cleaner Production (RECP) approach in the sector to make industrial production more sustainable • Invest in preparing hazard maps of low-lying industrial areas vulnerable to inundation, and develop DRRM strategies accordingly	• Formulate guidelines and policies related to health insurance to support laborers working in the sector • Retrofit, and ensure the modification of the existing scope of industries and physical structures, and update the industrial policies and standards according to long term (2050) climate projections • Allocate or develop alternative routes and ensure regular maintenance and monitoring to enable transportation of goods during emergencies • Formulate and implement appropriate policies and plans for the construction and manufacturing industries for consolidation of a low carbon economy

<table>
<tr><th>Risks and vulnerabilities</th><th colspan="3">Adaptation Options</th></tr>
<tr><th colspan="4">The Transport and Physical Infrastructure sectors</th></tr>
<tr>
<td rowspan="2">High risk and vulnerability due to increased climate extreme events and related loss and damages

High risks of disruption in the provision of necessary goods and services in rural and urban areas due to roadblocks and other damages, causing a problem for various groups

High risks of disruption of transportation services, creating problems for emergency health services, which may increase death tolls</td>
<td rowspan="2">• Develop and Implement climate-proofing infrastructure design practices including slope protection in Mountainous and hilly roads (more than 300) to reduce the Landslide vulnerability
• Carry out practical research on adaptation measures, both for current transportation systems and for the design of new systems and infrastructure; this is needed to better inform all kinds of transportation-related decisions as climatic conditions continue to worsen
• Develop alternative routes and transportation mechanisms to rescue people and ensure that stranded passengers get to their destinations
• Adjust safety factors in codes and standards (or other measures) for new infrastructure under changing climate conditions
• Develop and administer appraisal models for planning and design options to evaluate their potential costs from infrastructure damage and failure and service delays during disasters
• Support the transition to carbon-neutral, mass-transit systems and promotion of non-motorized transport (electric vehicle, cycling, and walking)</td>
<td>• Establish a georeferenced long term database to enable modeling and assessment of road and physical infrastructure projects in the context of extreme weather and climatic events</td>
<td>• Retrofit and modify the existing structure and update the design standard of (road, bridge, and airports concerning future climate projection (2050)</td>
</tr>
<tr>
<td>• Promote land zoning, ensuring that rural road projects include clear recommendations regarding land zoning that set prospective areas for settlements and buffer zones against landslides
• Set up roadside safety signs in areas susceptible to landslides, floods, and fires
• Establish an early warning and hazard communication systems for commuters and drivers and disseminate through SMS or ICT means
• Provide travel information that reduces the costs of extreme events by up to one third by helping users to avoid congestion through a combination of choosing other routes or rescheduling activities
• Demolish, replace or relocate unsafe structures or abandon high-risk locations in all municipalities
• Formulate and implement an integrated transport strategic planning framework that identifies co-benefits with the Low Emission Development Strategy
• Ensure cooperation amongst the sectoral bodies responsible for transport and mass-transit systems along with federal, provincial, and rural/municipal administrations</td>
<td>• Promote practices to increase slope stability and reduce erosion, such as reducing gradients of roadside slopes, constructing masonry retaining walls, and planting trees and vegetation along roadways
• Build embankments and walls by major rivers to prevent complete failures of major infrastructure such as bridges, roads, canals, dams and protect low-lying communities and infrastructure against flooding
• Develop certification standards for climate-proofing transport infrastructure and establish enforcement measures to ensure compliance
• Promote risk-sensitive infrastructure guidelines, e.g., for considering landslide hazards while designing the alignments of roads and other transport infrastructure. The integration of landslide risk data into development projects may have technical and financial implications for those projects
• Integrate climate-resilient building practices into the construction and maintenance of key airports, national highways, and connecting roads</td>
</tr>
</table>

Chapter 8

Conclusion and Recommendations

8.1 Conclusion

The industry, transportation, and physical infrastructure (ITPI) sectors are strongly associated with a country's economic growth, population mobility, and future development. However, climate change impacts can harm these sectors through, for example, an increase in costs associated with transportation networks and industrial investments. To help minimize these costs and make these sectors resilient against impacts of climate change, this assessment report primarily sought to identify sector-specific climate change related vulnerabilities and risks as well as appropriate adaptation options.

The impacts of climate change are particularly pertinent to this sector given their life span and their high initial cost, as well as their essential role in the transportation of services, goods, and people. As the impacts of climate change increase, the vulnerability of the sector also increases. Therefore, understanding sector-specific vulnerabilities and risks is very important to ensure that the identified subsectors are well equipped to deal with the adverse impacts of climate change. This study is the first to examine the climate change related vulnerabilities, exposures, and risks in the ITPI sector of Nepal. Hopefully, it will pave the way for more such studies in the future.

Extreme climatic events like floods and landslides are observed very frequently and this sector is at the forefront of climate impact. In constructing likely future scenarios, major drivers of climate stress were identified through a literature review and stakeholder consultations at the national, provincial, and local levels. Looking at the current trends and future scenarios of such stressors, it can be projected that the frequency and magnitude of climate extreme events is likely to be much higher in the future than it is now, and may cause even more destruction. Additionally, it can be said that significant losses in one of the three dimensions of development (see Chapter 1) could create additional challenges for the country's overall development progress.

Exposure indicators like the number of registered vehicles, length of SRN, number of strategic bridges, number of airports, number of registered industries, and proportion of industry-dependent populations were found to be in increasing trends; and the districts with more exposure units—such as Kathmandu and Chitwan—received a high exposure rank. In addition, factors that affect the sectors' overall sensitivity to climate change include the amount of gravel and earthen roads, the condition of the bridges and different types of industries. In terms of adaptive capacity, it was found that structural robustness, insurance schemes for employees, skilled manpower in industry, proper river discharge estimation, sharing of blacktopped roads, public-private partnerships, and social security schemes add value to the overall adaptive capacity index. Increased adaptive capacity can lead to the transport and industrial sectors becoming more resilient against both foreseen and unforeseen disruptions, and maintaining their safety, efficiency, and services.

Sensitivity and adaptive capacity indicators like the condition and types of physical and institutional infrastructure, their proximity to hazards, and the number of people that depend on them for their livelihoods played a significant role in determining the different vulnerability ranks given to the districts. Vulnerability outcomes were high in districts that had high sensitivity and low adaptive capacity and vice versa. In total, seven districts (namely Dhading, Humla, Mugu, Dolpa, Nuwakot, Sindhupalchok, and Kavrepalanchok) were ranked as very highly vulnerable and 28 districts as highly vulnerable (Rolpa, Makawanpur, Rasuwa, Myagdi, Lamjung, Sunsari, Dolakha, Dhankuta, Rautahat, Baglung, Bardiya, Gorkha, Lalitpur, Tanahu, Dailekh, Udayapur, Pyuthan, Siraha, Arghakhanchi, Sindhuli, Manang, Eastern Rukum, Kalikot, Jajarkot, Jumla, Parsa, Gulmi and Ilam). These districts were characterized by more vulnerable industrial companies and transport infrastructures including road and air transport both.

Considering the current levels of exposures, vulnerabilities, and risks, the projections of future climate stressors, and Nepal's current development trajectory, it is likely that future climate change will generally raise risk levels in the ITPI. At the baseline, ten districts fell in the very high risk category, but in long term projection for RCP 8.5 (2050), 16 districts were projected to come under the very high risk category. Only 15 districts in RCP 8.5 (2050) are expected to have very few issues in the ITPI due to climate change, while all others will face common but differentiated challenges.

8.2 Recommendations

- **Increase investment in sectoral capacity building:** Capacity building, data collection and sharing, policy development, and strategic planning are important for improving the adaptive capacity of vulnerable institutions. Additionally, efforts to safeguard people who rely on industrial services and transport networks should be increased.
- **Fill data gaps and zone the risk-sensitive areas in the ITPI:** The identification of transport assets and industrial areas at risk from climate change is a complex and long term endeavor, in which the consideration of accurate transport infrastructure data along with projections is just a first step. Therefore, regular assessment and zoning of the risk-sensitive areas is recommended.

- **Facilitate easy accessibility of information:** In this study, limited data prevented many relevant indicators of sensitivity and adaptive capacity from being taken into account. The availability of this information in a consistent and easily accessible manner would permit a more comprehensive analysis, and allow future studies to build on this one.
- **Increase the scope of vulnerability and risk assessments in the future**: This VRA study covered only districts, provinces, and physiographic regions due to data limitations. It is necessary to have VRAs at all local levels so that adaptation options can be adapted to local contexts and demands.

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Annexes

Annex 1: Exposure indicators and individual weightage

Exposure	Weight
Vehicles in operation (both private and public)	0.207
Fuel storage and charging stations (petrol pumps, oil/gas depo)	0.186
Strategic Road Network (SRN	0.219
Strategic bridges (including suspension)	0.212
No. of airports	0.174
Industries in operation	0.506
Population (no. of employees) in the industry	0.493

Annex 2: Sensitivity indicators and individual weightage

Sensitivity	Weight
Traffic flow (types of the vehicle)/annual average daily traffic	0.044
Population influenced per km. road	0.038
Age of vehicles in use in terms of their models	0.040
Fatality ratio	0.041
GHG/CO2 emissions from transportation	0.044
Types of the fuel station	
a. Permanent	0.074
b. Semi-permanent	0.112
Types of road	
a. ER	0.044
b. GR	0.029
Quality of road	
a. SDI	0.037
b. IRI	0.037
Proximity to hazard - Road	
a. Slope of road	0.024
b. Landslide	0.023
c. Flood	0.023
Condition of Bridge	0.110
Proximity to hazard - Bridge	
a. Proximity to landslide	0.051
b. Proximity to flood	0.051
Geographic location of airport	0.061
The built-up area of the airport	0.057
Types of the airport (paved/ non-paved)	0.056
Types of industry	
a. Agriculture	0.113
b. Construction	0.013
c. Energy	0.093
d. Information and technology	0.006
e. Manufacturing	0.006
f. Minerals	0.003
g. Service	0.003
h. Tourism	0.013
The scale of investment in the industry	
a. Large	0.039
b. Medium	0.039
c. Small	0.039
GHG/CO2 emissions	0.138
Number of male employees in the industry	0.128
Number of female employees in the industry	0.128
GDP contribution by industry	0.237

Annex 3: Sensitivity indicators and individual weightage

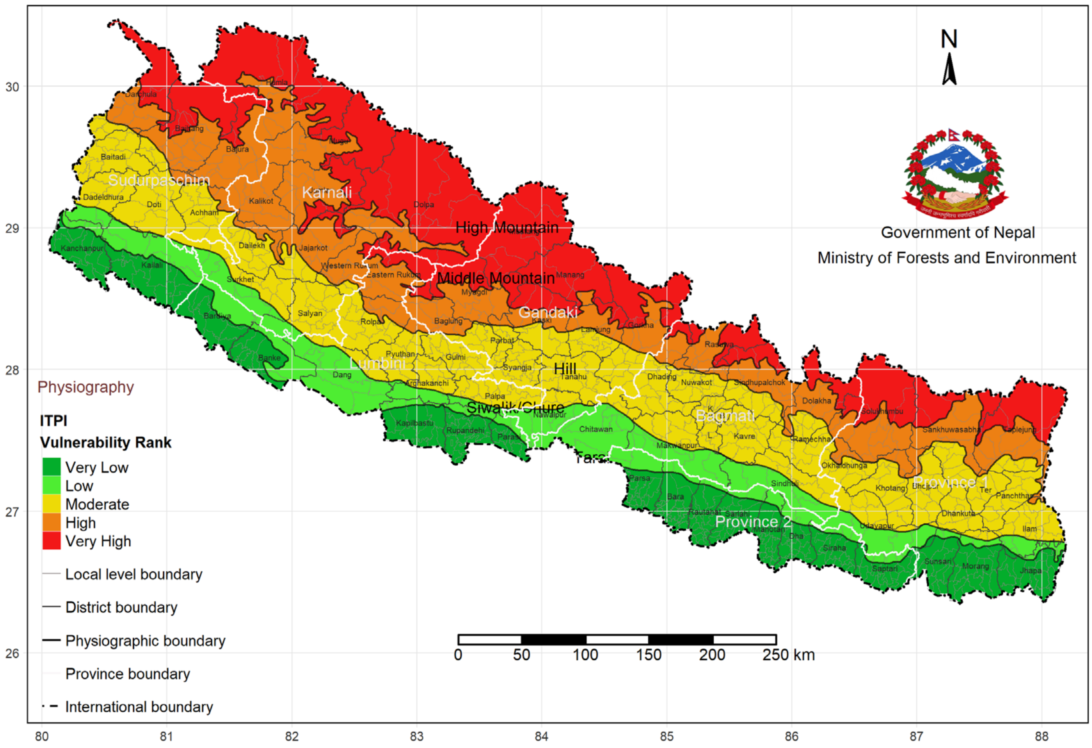
Adaptive Capacity	Weight
Pollution compliance policies and plans in place	0.039
E-mobility policies and plans in place	0.036
Access to the insurance system	0.032
Access to information about conditions of roads	0.035
Efficient traffic management system	0.039
Compliance and standards in place	0.192
Share of black-topped or concrete road	0.039
Retention wall in landslide-prone and flood prone area	0.046
National Road Standard (provision of road drainages at proper location with adequate size and shape)	0.046
Road safety standard including an early warning system	0.047
Investment including repair and maintenance	0.047
Structural robustness	0.110
Proper discharge estimation during the construction of bridges	0.109
Flight holding and enough aircraft park facilities	0.088
ATC tower and robust weather forecasting and information flow mechanism	0.092
Emission reduction schemes or pollution control measures	0.139
Public-Private Partnership	0.121
Skill acquisition and training facilities	0.123
Social security schemes in place	0.215
Insurance for the employees and employer	0.206
GESI friendly policies in place	0.196

Annexes 4 and 5. Vulnerability, Hazard and Risk Index for all 77 districts

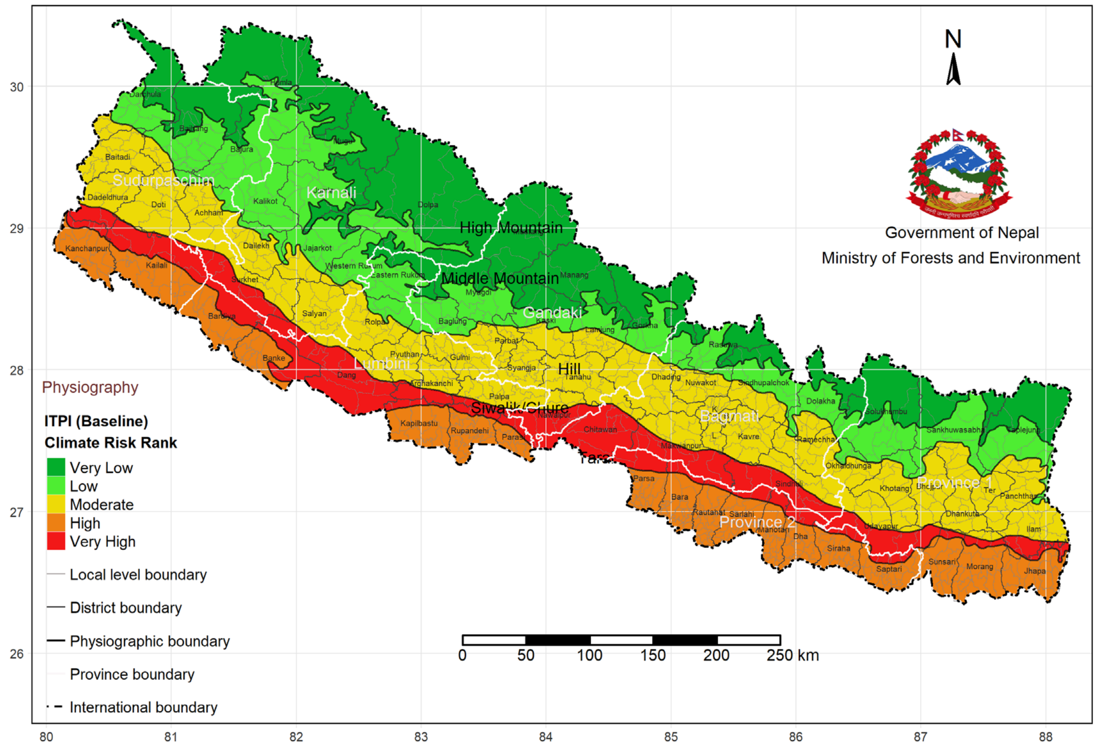
District	Exposure	Sensitivity	AC	Vulnerability	Baseline context of climate extreme events	Climate extreme events composite (RCP4.5 2030)	Climate extreme events composite (RCP4.5 2050)	Climate extreme events composite (RCP8.5 2030)	Climate extreme events composite (RCP8.5 2050)	Baseline Risk	RCP 4.5 2030 Risk	RCP 4.5 2050 Risk	RCP 8.5 2030 Risk	RCP 8.5 2050 Risk
Achham	0.165	0.543	0.527	0.269	0.555	0.485	0.585	0.472	0.61	0.074	0.065	0.078	0.063	0.082
Arghakhachi	0.229	0.632	0.459	0.599	0.661	0.616	0.695	0.622	0.774	0.25	0.233	0.263	0.235	0.293
Baglung	0.311	0.649	0.497	0.566	0.564	0.605	0.693	0.592	0.759	0.276	0.296	0.339	0.289	0.371
Baitadi	0.221	0.568	0.549	0.284	0.537	0.518	0.613	0.501	0.648	0.101	0.097	0.115	0.094	0.122
Bajhang	0.137	0.594	0.519	0.399	0.418	0.415	0.491	0.383	0.524	0.066	0.065	0.077	0.06	0.082
Bajura	0.107	0.545	0.53	0.266	0.398	0.39	0.461	0.368	0.506	0.034	0.033	0.04	0.032	0.043
Banke	0.517	0.577	0.601	0.21	0.564	0.534	0.631	0.53	0.68	0.192	0.182	0.215	0.181	0.232
Bara	0.573	0.682	0.69	0.286	0.618	0.634	0.679	0.639	0.786	0.302	0.31	0.332	0.313	0.385
Bardiya	0.432	0.696	0.547	0.581	0.582	0.537	0.635	0.537	0.678	0.404	0.373	0.441	0.373	0.471
Bhaktapur	0.377	0.734	0.671	0.438	0.582	0.627	0.673	0.623	0.805	0.273	0.294	0.316	0.292	0.378
Bhojpur	0.202	0.559	0.534	0.291	0.516	0.577	0.612	0.558	0.782	0.091	0.101	0.108	0.098	0.137
Chitwan	0.713	0.855	0.8	0.478	0.622	0.646	0.705	0.664	0.818	0.597	0.62	0.677	0.638	0.786
Dadeldhura	0.118	0.548	0.527	0.279	0.553	0.524	0.617	0.516	0.664	0.055	0.052	0.061	0.051	0.065
Dailekh	0.204	0.677	0.482	0.66	0.498	0.475	0.574	0.462	0.595	0.184	0.175	0.212	0.171	0.22
Dang	0.55	0.787	0.738	0.434	0.571	0.555	0.642	0.551	0.696	0.388	0.377	0.436	0.374	0.472
Darchula	0.165	0.584	0.544	0.33	0.462	0.448	0.531	0.432	0.571	0.074	0.072	0.085	0.069	0.091
Dhading	0.442	0.838	0.52	0.957	0.551	0.613	0.688	0.599	0.78	0.626	0.696	0.781	0.681	0.886
Dhankuta	0.189	0.606	0.438	0.578	0.553	0.617	0.665	0.617	0.83	0.168	0.187	0.202	0.187	0.252
Dhanusa	0.525	0.677	0.668	0.314	0.565	0.587	0.608	0.606	0.776	0.275	0.286	0.296	0.295	0.378
Dolakha	0.433	0.783	0.626	0.634	0.539	0.557	0.61	0.575	0.776	0.408	0.421	0.461	0.435	0.587
Dolpa	0.108	0.562	0.243	0.838	0.322	0.324	0.398	0.296	0.439	0.079	0.079	0.097	0.073	0.108
Doti	0.239	0.592	0.5	0.43	0.533	0.513	0.613	0.491	0.636	0.156	0.15	0.179	0.143	0.186
Eastern Rukum	0.17	0.585	0.385	0.626	0.51	0.505	0.583	0.479	0.621	0.15	0.148	0.171	0.141	0.183
Gorkha	0.232	0.725	0.544	0.654	0.445	0.491	0.577	0.475	0.646	0.185	0.204	0.24	0.198	0.269
Gulmi	0.239	0.665	0.471	0.65	0.591	0.64	0.724	0.634	0.793	0.252	0.273	0.308	0.27	0.338
Humla	0.106	0.591	0.232	0.924	0.349	0.331	0.39	0.299	0.434	0.092	0.087	0.103	0.079	0.114
Ilam	0.25	0.672	0.515	0.586	0.654	0.732	0.778	0.866	0.947	0.265	0.296	0.315	0.351	0.383
Jajarkot	0.11	0.538	0.331	0.62	0.498	0.492	0.577	0.462	0.598	0.094	0.093	0.109	0.087	0.113
Jhapa	0.536	0.734	0.787	0.225	0.72	0.783	0.821	0.966	1	0.269	0.293	0.307	0.361	0.374
Jumla	0.148	0.594	0.434	0.555	0.462	0.447	0.512	0.413	0.55	0.105	0.102	0.117	0.094	0.125
Kailali	0.648	0.714	0.717	0.306	0.59	0.548	0.644	0.541	0.681	0.347	0.322	0.378	0.318	0.4
Kalikot	0.085	0.538	0.365	0.557	0.44	0.425	0.505	0.399	0.529	0.058	0.056	0.067	0.053	0.07
Kanchanpur	0.308	0.621	0.6	0.31	0.593	0.55	0.628	0.537	0.69	0.167	0.155	0.177	0.151	0.194
Kapilbastu	0.486	0.6	0.579	0.303	0.609	0.602	0.668	0.626	0.753	0.266	0.263	0.292	0.274	0.329
Kaski	0.418	0.768	0.851	0.183	0.574	0.618	0.706	0.616	0.789	0.142	0.153	0.175	0.152	0.195
Kathmandu	1	1	1	0.438	0.579	0.64	0.688	0.626	0.804	0.72	0.796	0.856	0.778	1
Kavrepalanchok	0.422	0.905	0.579	1	0.581	0.623	0.664	0.631	0.81	0.657	0.705	0.751	0.714	0.916
Khotang	0.345	0.541	0.56	0.202	0.5	0.551	0.585	0.543	0.757	0.11	0.122	0.129	0.12	0.167
Lalitpur	0.528	0.979	0.843	0.681	0.576	0.616	0.658	0.619	0.792	0.567	0.606	0.648	0.609	0.779
Lamjung	0.132	0.632	0.462	0.592	0.536	0.59	0.683	0.581	0.76	0.116	0.128	0.148	0.126	0.165

District	Exposure	Sensitivity	AC	Vulnerability	Baseline context of climate extreme events	Climate extreme events composite (RCP4.5 2030)	Climate extreme events composite (RCP4.5 2050)	Climate extreme events composite (RCP8.5 2030)	Climate extreme events composite (RCP8.5 2050)	Baseline Risk	RCP 4.5 2030 Risk	RCP 4.5 2050 Risk	RCP 8.5 2030 Risk	RCP 8.5 2050 Risk
Mahottari	0.411	0.682	0.578	0.492	0.575	0.595	0.621	0.639	0.769	0.326	0.338	0.352	0.362	0.436
Makawanpur	0.585	0.895	0.741	0.678	0.61	0.64	0.693	0.63	0.793	0.663	0.695	0.753	0.684	0.861
Manang	0.097	0.575	0.434	0.514	0.348	0.377	0.457	0.358	0.514	0.048	0.052	0.064	0.05	0.071
Morang	0.567	0.691	0.729	0.231	0.639	0.687	0.728	0.787	0.885	0.259	0.278	0.295	0.319	0.359
Mugu	0.071	0.559	0.225	0.864	0.367	0.345	0.406	0.299	0.434	0.061	0.057	0.067	0.05	0.072
Mustang	0.196	0.497	0.423	0.355	0.256	0.276	0.362	0.268	0.417	0.052	0.056	0.073	0.054	0.084
Myagdi	0.082	0.598	0.438	0.559	0.495	0.52	0.602	0.516	0.677	0.063	0.066	0.076	0.065	0.086
Nawalpur	0.307	0.553	0.461	0.412	0.628	0.65	0.705	0.685	0.833	0.227	0.235	0.255	0.248	0.301
Nuwakot	0.376	0.809	0.525	0.881	0.561	0.636	0.709	0.621	0.808	0.501	0.568	0.633	0.555	0.722
Okhaldhunga	0.205	0.494	0.569	0.077	0.51	0.549	0.58	0.561	0.757	0.033	0.036	0.038	0.037	0.049
Palpa	0.293	0.615	0.542	0.406	0.619	0.671	0.737	0.679	0.835	0.21	0.228	0.25	0.231	0.284
Panchthar	0.224	0.575	0.445	0.493	0.583	0.672	0.72	0.738	0.89	0.181	0.209	0.224	0.229	0.276
Parasi	0.316	0.583	0.556	0.306	0.628	0.65	0.705	0.685	0.833	0.18	0.186	0.202	0.196	0.238
Parbat	0.117	0.552	0.414	0.499	0.629	0.689	0.778	0.684	0.853	0.103	0.113	0.128	0.112	0.14
Parsa	0.425	0.722	0.538	0.657	0.622	0.623	0.676	0.668	0.806	0.477	0.478	0.519	0.512	0.618
Pyuthan	0.227	0.644	0.462	0.619	0.568	0.588	0.673	0.575	0.727	0.22	0.228	0.26	0.222	0.281
Ramechhap	0.334	0.689	0.62	0.43	0.53	0.555	0.59	0.57	0.762	0.217	0.227	0.241	0.233	0.312
Rasuwa	0.3	0.694	0.546	0.578	0.437	0.488	0.575	0.471	0.665	0.21	0.235	0.277	0.226	0.32
Rautahat	0.361	0.704	0.553	0.589	0.597	0.63	0.67	0.618	0.765	0.352	0.371	0.395	0.364	0.45
Rolpa	0.276	0.658	0.486	0.607	0.537	0.54	0.633	0.512	0.663	0.248	0.249	0.292	0.236	0.306
Rupandehi	0.646	0.741	0.765	0.28	0.619	0.615	0.664	0.645	0.777	0.335	0.333	0.36	0.349	0.421
Salyan	0.119	0.544	0.4	0.506	0.537	0.523	0.624	0.503	0.644	0.09	0.088	0.105	0.085	0.108
Sankhuwasabha	0.275	0.597	0.633	0.195	0.609	0.667	0.727	0.656	0.885	0.104	0.114	0.124	0.112	0.151
Saptari	0.592	0.647	0.616	0.34	0.559	0.591	0.613	0.852	0.877	0.329	0.348	0.361	0.501	0.516
Sarlahi	0.41	0.695	0.609	0.463	0.585	0.619	0.656	0.628	0.779	0.314	0.332	0.352	0.337	0.418
Sindhuli	0.529	0.804	0.632	0.671	0.569	0.607	0.636	0.615	0.791	0.553	0.59	0.618	0.598	0.769
Sindhupalchok	0.42	0.845	0.598	0.829	0.547	0.587	0.663	0.604	0.802	0.515	0.552	0.624	0.568	0.755
Siraha	0.411	0.688	0.541	0.576	0.554	0.58	0.597	0.755	0.766	0.363	0.38	0.392	0.495	0.502
Solukhumbu	0.258	0.645	0.562	0.437	0.485	0.518	0.57	0.511	0.711	0.155	0.166	0.183	0.164	0.228
Sunsari	0.442	0.734	0.616	0.539	0.589	0.635	0.666	0.675	0.828	0.39	0.421	0.441	0.447	0.549
Surkhet	0.33	0.665	0.61	0.393	0.543	0.513	0.615	0.507	0.644	0.202	0.191	0.229	0.189	0.24
Syangja	0.214	0.586	0.488	0.437	0.644	0.707	0.793	0.707	0.87	0.171	0.188	0.211	0.188	0.231
Tanahu	0.304	0.721	0.526	0.678	0.636	0.696	0.78	0.703	0.86	0.36	0.394	0.441	0.398	0.486
Taplejung	0.169	0.609	0.572	0.335	0.543	0.621	0.685	0.61	0.828	0.09	0.103	0.113	0.101	0.137
Terhathum	0.149	0.558	0.436	0.469	0.556	0.643	0.691	0.648	0.864	0.11	0.127	0.137	0.128	0.171
Udayapur	0.37	0.734	0.544	0.674	0.528	0.58	0.608	0.587	0.778	0.362	0.397	0.416	0.402	0.532
Western Rukum	0.183	0.646	0.523	0.511	0.51	0.505	0.583	0.479	0.621	0.133	0.132	0.152	0.125	0.162

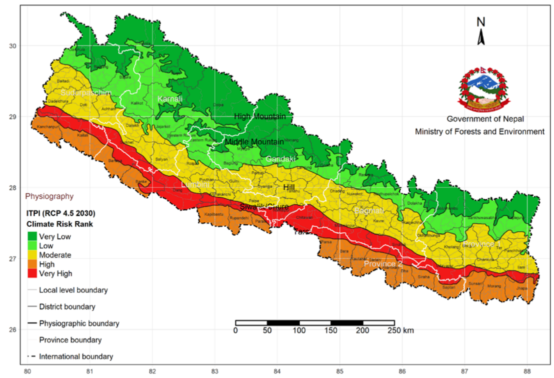
Annex 6: Physiographic Vulnerability Map



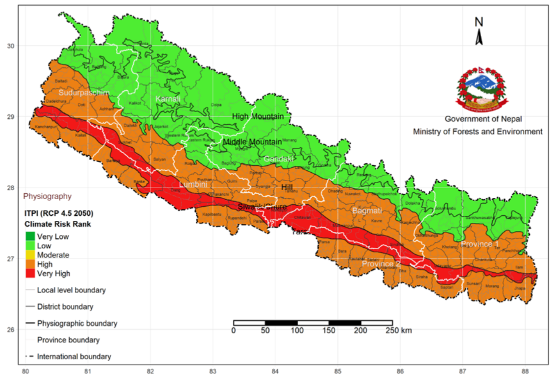
Annex 7: Physiographic Risk Map



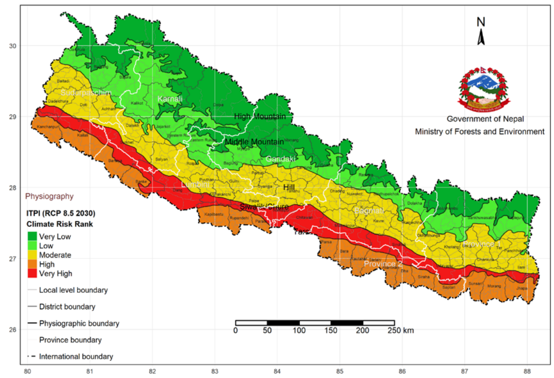
Annex 8: Physiographic Risk Scenarios



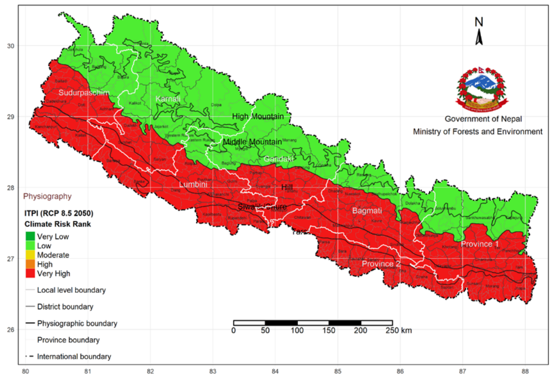
RCP 4.5 - 2030



RCP 4.5 - 2050



RCP 8.5 - 2030



RCP 8.5 - 2050

Annex 9: Summary findings of provincial consultations on the ITPI

Mountains: According to the provincial consultations, rising temperatures, precipitation variability and the increasing trend of disasters are some of the major climate stressors in the mountainous region of Nepal. While the impact of climate change is very direct for all sectors, agriculture is on the front line. The decline in production, disturbances in supply mechanisms, and shortage of raw materials are some of the immediate impacts in the industrial sector. Additionally, people depending on industrial services like entrepreneurs, labourers, and vulnerable groups are found to be highly impacted. It was also pointed out that infrastructure such as trails, bridges, and highways are also very vulnerable to GLOFs and landslides.

Suggested Adaptation Options:
- Invest in high technology and technology development
- Capacity building of private sectors, people engaged in tourism, and industry sector regarding impacts of climate change
- Promote early warning systems and reinforce building code and infrastructure development codes

Hills: Intense rainfall (more rain in short duration), fires, landslides, and flash floods are the main extreme events resulting from temperature increase and rainfall variation. According to the stakeholders, these events have resulted in enormous economic losses due to the leaching of physical infrastructures such as industrial buildings, roads, bridges, and water reservoirs. The most impacted groups include the investors, service providers (transport companies, transport owners and owners of industries), and beneficiaries like commuters, employees, and other populations dependent on these infrastructures.

Suggested adaptation options
- Develop guidelines to regulate the haphazard construction of roads
- Develop standards and guidelines for climate-resilient physical infrastructure development
- Increase awareness of the private sector and entrepreneurs of the need to develop adaptation measures to reduce the impact of climate change
- Develop and implement building codes and infrastructure guidelines to make it more environmentally and climate-friendly
- Promote bioengineering practices to stabilize roads
- Develop alternative routes and increase awareness and sensitization of pubic and user groups

Terai: Extreme temperatures, droughts, heatwaves and cold waves, flooding, and inundations are the main climate extreme events in the Terai region. Floods cause significant economic losses in the industrial sector, including damage to roads, bridges, culverts, drains, and, in particular, the transportation of people and goods. According to the consultations, workers, women, senior citizens, people with disabilities, and people with health problems are particularly at risk. Similarly, problems including damage to infrastructures, increased fatigue of infrastructures, silting of drains, and increased instability of land through the weakening of riverbanks or hill toes or land subsidence, maximum cases of floods and inundations, and submergence of infrastructures are anticipated to become more common in the Terai region.

Suggested Adaptation Options

- Invest in repair and maintenance of infrastructures regularly
- Implement an early warning system for floods and fires
- Promote riverbank protection and bioengineering to reduce the impacts of flooding
- Promote sustainable and resilient city and settlement patterns

In all three regions, people including children, women, people with physical disabilities, indigenous groups, small business holders, young entrepreneurs, and people depending directly and indirectly on industries were considered to be the most vulnerable to climate change impacts. Such insights can and should be provided to the policymakers so that can they enable the resilience of the transportation sector. To identify the current transportation and infrastructure constraints, a broad-brush approach of reviewing past efforts and past developmental activities is needed. This would help in policymaking, setting standards and guiding the ITPI towards sustainability. Promotion of bioengineering works on the roadside, early warning systems in disaster-prone areas, research related to the ITPI and climate change, implementation of climate-friendly technology and infrastructures, and sustainable and resilient city and building codes can improve the prospects of these sectors substantially by make them less vulnerable to climate change impacts.

More detailed results of the province-wise consultations are given in the tables below.

1. Province 1: Biratnagar

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Lon- term adaptation options
Mountain					
Extreme cold GLOF potential LDOF potential	Temperature is increasing rapidly in the mountains. E.g. Taplejung the highest in Nepal Rainfall variability: less rainfall projected Increasing trend of disasters	Impact on agricultural industries (livestock products related); production decline, particularly of livestock due to changes in the pasture areas Impact on the tourism industry: reduced tourist flow, less income and less employment Small cottage industries likely be impacted due to scarce raw materials Market disruption due to lack of transportation access both air and land GLOFs damaging infrastructure such as trails, bridges and hydropower stations	People depending on industrial sector Entrepreneurs and small businesses Labourers Women, elderly, people with disability and people with health issues	Invest in high technology and technology development Capacity building of private sectors and people engaged in tourism, industry sector about the impact of climate change Carry out research on how climate change impacts the sector in the mountainous regions Establish industrial zones to protect and incentivize industries	Promote early warning systems Reinforce building codes and infrastructure development codes

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Lon- term adaptation options
Hills					
Intense rainfall – more rain in short duration Drought Fire Landslide Flash Flood	Temperature is rising Rainfall is uncertain with high variability; shifts in monsoon No winter rains Landslides and fires are rampant	Damage to infrastructure and roads: massive landslides and flash floods washing roads, buildings, bridges, trails, etc. Damage to small industries, agriculture enterprises, NTFP enterprises Human migration due to lack of access to goods and services Overall, the poverty and vulnerability has increased due to economic and social loss and damage	People depending on industrial sector Entrepreneurs and small businesses Labourers Women, elderly, people with disability and people with health issues	Develop guidelines to regulate the haphazard construction of roads Develop standards and guidelines for climate resilient physical infrastructure development Increase awareness of private sector and entrepreneurs on the need to develop adaptation measures to reduce the impact of climate change Promote building codes Promote bioengineering practices to stabilize roads Develop alternative routes	Develop and implement building codes and infrastructure guidelines to make it more environment and climate friendly
Terai					
Extreme heat (temperature increase) Droughts Heatwaves and cold waves Flooding and inundation	All in increasing trend Loss and damage are huge, in particular economic losses Floods and landslides are rampant, damaging infrastructure and properties Outbreak of diseases and sanitation issues	Industries impacted due to flooding triggering economic losses Damage to road, bridges, culverts, and drainage Damage to sewerage system and drinking water facilities, causing drinking water problem and sanitation issues	People depending on industrial sector Entrepreneurs and small businesses Labourers Women, elderly, people with disability and people with health issues	Invest in repair and maintenance of infrastructures regularly Develop guidelines and standards and codes to regulate the haphazard construction of physical infrastructure Promote riverbank protection and bioengineering to reduce the impacts of flooding	Promote sustainable and resilient cities and settlement patterns

2. Province 2: Janakpur

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Heavy rainfalls in short duration Increasing flood incidences Increasing temperatures Massive loss of life and property	Temperature in Terai has increased rapidly, the summer hotter and winter also warming More frequent and massive floods Increase in incidences of new diseases	Disruption of road and transport services due to floods, fog and cold waves Closure of industries due to impact of flooding Lack of access to goods and services needed daily Disruption of the services sector	Mostly poor and marginalized, the Dalit and other ethnic minority groups	Promote practices of water draining while constructing roads Ensure environmental rules compliance for industries Ensure compliance with emissions tracking for vehicles	Promote early warning systems for floods Develop and implement climate resilient standards and protocols for transport and infrastructures Promote use of electric vehicles Make the road and industries climate and environment friendly Ensure proper drainage systems

3. Bagmati Province: Hetauda

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Mountain, Hills and Terai					
Lack of raw materials Disruption in electricity transmission Impact on water resources and irrigation infrastructures Floods and landslides Migration due to climate change Disruption of services such as transportation	Increasing temperatures and changes in rainfall Increase in extreme events and their impacts	Impact on infrastructure: roads, bridges, culverts, buildings, transmission lines, water pipes, hydropower stations Impact on transport: air and road, due to weather events and impacts Impact to industries: loss and damage Impact to populations: lack of transportation, disruption of services, communication disruptions, school closures etc. Disruption in market: farmers cannot sell their products during road blocks or landslides Increase in accidents due to slippery roads, narrow roads and landslides	Ordinary people, people with disability, the elderly and children Transport and industry entrepreneurs Aviation industry Women and girls during disasters and road blockages	Promote early warning systems and increase access of communities and business owners to knowledge about risks Promote effective rescue and relief at local, provincial and federal levels Awareness and sensitization of private sectors about the need to develop climate resilient systems	Ensure infrastructure development follow climate resilience standards and codes Implement strict guidelines to stop haphazard road construction Develop alternative routes and safe passage for stranded passengers and commuters Promote warning systems for floods and landslides Ensure use of bioengineering practices while constructing roads Introduce efficient technologies for making the industry sector more carbon neutral

4. Gandaki Province: Pokhara

Challenges and disaster events	Impact	Medium term adaptation plan	Long term adaptation plan
Mountains			
Snow avalanches and GLOFs Temperature rise Change in time of snowfall	Settlement displaced Loss of lives and property Decline in rate of migration from mountain to hills Annapurna Rural municipality observed land degradation resulting into settlement Displacement Impact to physical infrastructure	Early warning systems Risk mapping and zonation Climate resilient design	Planned relocation of settlements to non-risk zones Stringent compliance to EIA and IEE
Hills			
Rainfall variability: heavy rain, no rain and sporadic rain Hailstones Droughts Temperature rise Floods Landslides	Drying up water sources leading to inaccessibility of water Loss and damage to physical infrastructure Loss of production of industrial raw materials Traffic congestion Decline in river water flow resulting in decline in electricity production Loss of lives and property Settlements displaced Unplanned migration of settlements Unplanned urbanization Impact the most vulnerable groups, including women, children, senior citizens, differently abled people	Early warning system Risk/hazard mapping Climate resilient design Bioengineering Relocation plan Physical infrastructure development designed with vulnerable groups in mind	Building code implementation Integration of rainwater harvesting in building permit Integration of concept of recharge pits and recharge ponds in building permit systems, from household to large scale Integration of land use plan in building permit system Assurance of equitable access of physical infrastructure and services to all

5. Lumbini Province: Butawal

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Mountains					
Rapid ice melting GLOFs Avalanches Extreme temperature increase Rainfall changes	Decrease in level of snow Increase in GLOFs Increase in avalanche incidences Variability in rainfall observed Increase in temperature	The tourism flow is decreasing High risk of GLOFs Impact to transportation due to extreme weather events, with frequency of accidents increased Shifting of vegetation is impacting the loss of species The livelihood of mountain people is impacted negatively	Community dependent on tourism sector for livelihood Porters and tourists Private sector and entrepreneurs	Make the tourism flow more organized Establish early warning systems – e.g., siren Develop physical infrastructure codes and guidelines for promoting resilience Improve communication systems for informing the tourists and communities about risks Effective rescue and relief mechanisms in place	Safe settlement of households impacted Improved early warning and communication systems Establish risk monitoring systems in the mountains Provide timely information to the tourists and tourism sector Develop alternative tourist routes and destinations Implement insurance systems in partnership with the private sector

Challenges posed by climate change and extreme events	Trends of the changes	Impacts and vulnerabilities	Who is or what is most impacted?	Medium-term adaptation options	Long-term adaptation options
Hills					
Increasing temperature Extreme variability in rainfall pattern Extreme events e.g., floods and landslides Increase in incidences of forest fire	Increase in temperature Variability in rainfall Increased in extreme events	Increase in flash floods and landslide, damaging roads, infrastructures and industries Increased in flash flood and landslides, disrupting communication and transport Agriculture crops not getting access to market due to disruptions Increase in number of accidents and deaths Huge economic losses due to landslides and their impact on physical infrastructures such as road, trails, bridges, water services Disruption of schools	Entrepreneurs Business owners Commuters Farmers Children	Strict regulation to control haphazard road construction Awareness and sensitization to people involved in physical infrastructure development Regulations to make construction of roads, industries and physical infrastructure more climate resilient Promote bio-engineering Promote water storage	Implement programmes to climate-proof infrastructures Promote regular repair and maintenance of infrastructure Allocate enough budget to manage risk from climate impacts Develop technology that can help infrastructure withstand physical damages eclare conservation areas
Terai					
Increase in temperature Increase or decrease in rainfall Floods, fires, heatwaves	Rapid increases in temperature and frequency of extreme events such as heavy rainfall, heatwaves, coldwaves	Damage to roads, buildings, bridges, water services, drainages Damage to industries Disruption of services (transport, production, processing) Disruption of air transport	Ordinary people Businesses and business owners Entrepreneurs Farmers Labors	Promote sustainable cities Riverbank protection and plantation activities Promote bio-engineering Promote water storage facilities and sanitation	Implement standards and codes for industries, transport and physical infrastructure Promote safety measures while constructing houses and infrastructure in flood plain areas Promote flood control measures Implement insurance mechanisms

Annex 10: First TWG meeting participants list

S. N.	Name	Designation
1	Mr. Saroj Kumar Pradhan	Joint Secretary- MoPIT
2	Ms. Srijana Shrestha	Under Secretary, MoFE
3	Dr Bimal Raj Regmi	Team Lead PIF/OPM
4	Mr. Surendra Raj Pant	CCMD, MoFE
5	Mr. Rajan Thapa	Thematic Expert, PIF/OPM
6	Ms. Binaya Parajuli	Assistant Gender Affairs and M&E Officer, UNEP
7	Mr. Amrit Nakarmi	IOE
8	Sagar Adhikari	ICIMOD
9	Mr. Gyanendra Karki	Project Coordinator, UNEP/NAP
10	Dr Bhogendra Mishra	GIS Expert, PIF
11	Ms. Kabita Mandal	Communications Consultant, UNEP
12	Mr. Suresh Shrestha	
13	Dr Shree Bhagwan Thakur	Consultant, UNEP
14	Ms. Gita GC	Thematic Expert, PIF/OPM
15	Ms. Shalu Adhikari	Expert, UNEP
16	Mr. Piyush Chataut	Engineer
17	Mr. Bhupendra Shrestha	Senior Divisional Engineer
18	Mr. Basanta Poudel	UNEP/NAP
19	Ms. Shova Bhandari	Sociologist
20	Mr. Raju Sapkota	MoFE
21	Er. Rajaram Pote Shrestha	WHO
22	Mr. Kedar Prasad Nepal	Senior Divisional Engineer
23	Dr Pashupati Nepal	Coordinator-VRA, PIF
24	Mr. Pabitra Gurung	Thematic Expert, PIF/OPM
25	Mr. Ananta Pandey	GGGI
26	Mr. Manoj Aryal	Environmental Inspector
27	Ms. Basana Sapkota	GESI Expert
28	Mr. Subha Shrestha	DoR
29	Mr. Sujan Shrestha	Program Management Assistant, UNEP
30	Mr. Pratik Ghimire	Logistics Support, PIF/OPM

मिराज डेण्टल
LAVA
TUBORG
UNIVERSAL STAR
FOOD LAND
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