MINISTRY OF PHYSICAL INFRASTRUCTURE DEVELOPMENT

BAGMATI PRADESH GOVERNMENT, HETAUDA

CLIMATE RESILIENT PROVINCIAL ROAD INFRASTRUCTURE DESIGN AND DEVELOPMENT DIRECTIVE, 2026

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Note: The cover page infographic communicates the title "CLIMATE RESILIENT PROVINCIAL ROAD INFRASTRUCTURE DESIGN AND DEVELOPMENT DIRECTIVES, 2026" for Bagmati Pradesh with a clean, authoritative style and symbolic elements of resilience like bridges, green buildings, solar panels indicating the use of clean energy, and natural landscape.

FOREWORD

It is with great pleasure and satisfaction that I write my words of appreciation and thanks to the experts and ministry colleagues and present this technical directive document titled: *Climate Resilient Provincial Road Infrastructure Design and Development Directives, 2026 (Utthansheel Sadak Nirman Sambandhi Margdarshan, 2083)* of Bagmati Province government. This document is a landmark step in mainstreaming climate resilience into our provincial road infrastructure planning, design, and development processes.

Bagmati Province - with its location in central Nepal is well highlighted in the Global Climate Risk Index and national vulnerability assessments as a highly vulnerable to floods, landslides, glacial lake outburst floods, and urban heat stress. The increasing climate change induced risks and hazards threaten not only our road infrastructure but also the livelihoods, ecosystems, health, and cultural heritage of the Bagmati province. Responding to the climatic and non-climatic risks in an integrated manner, this guiding document or *MARGDARSHAN* provides a systematic and structured framework to ensure that every provincial road project integrates climate adaptation, disaster risk reduction, and nature-based solutions.

The technical directives and tools therein are fully aligned with Nepal's Constitution, Environment Protection Act (2076), National Adaptation Plan, and Nationally Determined Contributions (NDC 3.0), and Bagmati Province's infrastructure development master plan thereby reinforcing our commitment to a resilient, sustainable, and inclusive future for not only the current generation but also future generation of the people of Bagmati Pradesh and beyond.

I would like to sincerely appreciate the collective effort made by the Principal author Dr. Madhav Bahadur Karki, associate authors and other respectable Reviewers for their hard work and sincere effort in preparing this valuable directive document. I express my special thanks and deep appreciation to Mr. Ishwor Chandra Marahatta, Secretary of the Ministry of Physical Infrastructure Development (MoPID) for his valuable support, guidance and facilitation.

I sincerely hope that this document will help MOPID and Bagmati Pradesh Government to both mainstream and integrate climate change induced risks and hazards in the provincial road policy, plan and program leading to a climate resilient and sustainable development in the province.

Thank you.

Dr. Dinesh Chandra Devkota
Hon'ble Minister Ministry of Physical Infrastructure Development (MoPID)
Bagmati Province Government

ACKNOWLEDGMENT

On behalf of the Ministry of Physical Infrastructure Development (MoPID), Bagmati Province, it is my great pleasure to present this directive document entitled "Climate-Resilient Provincial Road Infrastructure Design and Development Directives, 2026 (JALBAYU UTTHANSHIL PRADESH SADAK NIRMAN MARGDARSHAN, 2083)." This publication has been prepared to serve policymakers, bureaucrats, engineers, practitioners, and other stakeholders engaged in the planning, design, development, and management of provincial road infrastructure.

This publication is the outcome of extensive consultations and collaborative engagement among MoPID officials, technical experts, and stakeholders under the guidance of the Honorable Minister of Physical Infrastructure Development, Bagmati Province. It is based on national policies and frameworks, including the Climate Change Policy (2019), the Disaster Risk Reduction and Management Act (2017), and the Local Adaptation Plans for Action (LAPA), while contextualizing these provisions to address the specific vulnerabilities and development needs of Bagmati Province.

The draft document underwent rigorous review and consultation with senior policymakers, bureaucrats, and subject-matter experts. I would like to extend special appreciation to the distinguished reviewers nominated by MoPID: Dr. Ganesh Raj Joshi, Former Secretary, Government of Nepal; Dr. Kedar Rijal, Professor, Central Department of Environmental Science (CDES), Tribhuvan University; and Er. Dinesh Bajracharya, Senior Water and Sanitation Consultant. Dr. Dinesh Manandhar, Expert Climate Change. Their insightful comments and constructive recommendations significantly enhanced the quality and relevance of this directive. I would like to express my sincere appreciation to the Principal Author, Dr. Madhav Bahadur Karki**,** Lead Consultant, and the Associate Consultants and Authors, Mr. Prajwal Rai, Road Engineer, and Dr. Dilli Poudel**,** Social and Livelihood Expert, for their dedicated efforts in preparing this practical, user-friendly, and technically robust document.

This **MARGADARSHAN** is envisioned as a living document and will be periodically updated to incorporate emerging knowledge, technologies, and best practices. It is my sincere hope that this directive will serve as a practical reference for engineers, planners, policymakers, and communities in developing climate-resilient provincial road infrastructure that safeguards lives, strengthens livelihoods, protects ecosystems, and promotes sustainable development across Bagmati Province.

Thank you.

Ishwor Chandra Marahatta
Secretary Ministry of Physical Infrastructure Development (MoPID)
Bagmati Province Government

Publication Brief:

BAGMATI PRADESH GOVERNMENT

CLIMATE RESILIENT PROVINCIAL ROAD INFRASTRUCTURE DESIGN AND DEVELOPMENT DIRECTIVES, 2026

The "Climate Resilient Provincial Road Infrastructure Design and Development Guiding Directive, 2026" is a technical directive document of the Ministry of Physical Infrastructure Development (MOPID), Bagmati Pradesh Government's long-term development vision.

Whereas the Constitution of Nepal (2015) and the relevant Environment Protection Act and Regulations of the Govt. of Nepal (GoN) mandate resilience integration in infrastructure development; Also whereas Bagmati Province is highly vulnerable to climate change induced risks and hazards as well as risks such as floods, landslides, GLOF, permafrost melting and heat waves such as urban heat islands (UHI); therefore, MoPID hereby issues the following Directives to ensure mainstreaming and integrating climate and disaster resilience risk reduction and adaptation considerations, factors and imperatives in planning, designing and construction of different types of provincial road infrastructure governed and managed by the MOPID, Govt. of Bagmati Province (GoBP).

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ADB	:	Asian Development Bank
BIM	:	Building Information Modeling
BoQ	:	Bill of Quantities
CCA	:	Climate Change Adaptation
CDKN	:	Climate and Development Knowledge Network/
DHM	:	Department Of Hydrology
DRR	:	Disaster Risk Reduction
EbA	:	Ecosystem-Based Adaptation
EIA	:	Environmental Impact Assessment
FY	:	Fiscal Year
GESI	:	Gender Equality and Social Inclusion
GIS	:	Geographic Information System
GLOF	:	Glacial Lake Outburst Flood
GLOFs	:	Glacial Lake Outburst Floods
GoBP	:	Government of Bagmati Province
GoN	:	Government of Nepal
ICIMOD	:	International Centre for Integrated Mountain Development
IDS	:	Institute of Development Studies
IUCN	:	International Union for Conservation of Nature
LID	:	Low-Impact Development
LTS	:	Long-Term Strategy for Emission Reduction
M&E	:	Monitoring And Evaluation
MoFE	:	Ministry Of Forests and Environment
MOHA	:	Ministry of Home Affairs
MoPID	:	Ministry of Physical Infrastructure

MRV	:	Monitoring, Reporting, And Verification
NAP	:	National Adaptation Plan
NAPA	:	National Adaptation Plan of Action
NbS	:	Nature-Based Solutions
NDC	:	National Determined Contribution
NDRRMA	:	National Disaster Risk Reduction and Management Authority
NPR	:	Nepalese Rupees
R2R	:	Risk To Resilience
REDD+	:	National Reducing Emissions from Deforestation and Forest Degradation
SDC	:	Sustainable Development Goals
UHI	:	Urban Heat Islands
UNDRR	:	United Nations Office for Disaster Risk Reduction
WB	:	World Bank

EXECUTIVE SUMMARY

The Global Climate Risk Index, 2025 ranks Nepal 69th among the world's most climate-vulnerable countries. Frequent disasters coupled with rising temperature and erratic rainfall is seriously affecting livelihoods, infrastructures, ecosystems, people, and geography. Additionally, rapid urbanization in the fragile terrain further exposes the development practices, increasing the risk of disasters. Bagmati Province, home to Kathmandu Valley, is one of the most vulnerable provinces due to the growing climate-induced risks and hazards. Nepal's major climate adaptation and mitigation policies and programmes, such as National Adaptation Plan (NAP), Nationally Determined Contribution (NDC), Long-term Strategy for Emission Reduction (LTS, SDG Strategy and Action Plan and the 16th National Development Plan have well recognized the growing risk of disasters and proposed multiple options for actions. Accordingly, to address the disasters, the government has implemented several climate policies such as the National Adaptation Program of Action (NAPA, 2010), the Climate Change Policy (2019), the Local Adaptation Plans for Action (LAPA framework (2011) as well as National Disaster Risk Management Strategy and Action Plan (2011), and Climate Resilient Planning (CRP) tool (2011) in Nepal. This CRP tool is a strategic, government-led initiative spearheaded by the National Planning Commission (NPC) and the Ministry of Forests and Environment (MoFE) to integrate climate change adaptation (CCA) and disaster risk reduction (DRR) directly into national, provincial, and local development plans. The goal is to move from reactive, short-term measures to proactive, long-term resilience, aligning with the 15th and 16th Periodic Plans, the National Climate Change Policy 2019, and the 3rd Nationally Determined Contributions (NDCs) to achieve a net-zero, resilient society by 2030/2045. Aligning the national policies, the Articles 11 and 30 of the Environment Protection Act (2076) of Nepal empowers the Provincial Government to require supplementary environment impact assessment (EIA) and make other special provision to ensure that road and other infrastructure development activities do not cause harm to natural and cultural heritages and resources. Additionally, the Environment Protection Regulations, Local Government Operation Act, and National Climate Change Policy are guiding federally enacted laws and policies which have assigned clear role for the provincial and local governments on climate change.

Bagmati province is one of the most vulnerable provinces and faces both extreme and slow-onset climate-related risks and hazards, stemming from a combination of fragile and sensitive mountainous topography, high population growth and degrading ecosystems, highly variable monsoon-driven hydrology, unplanned especially, dense urban settlements, and a lack of resilient infrastructure planning, design and development. Recent climatic shocks include the Melamchi Flood Disaster, 2021; Roshikhola Flood Disaster, 2024 and recurring Bhotekoshi landslides have caused significant economic loss and infrastructure damage. Floods and landslides were the most frequent hazards observed over the past 40 years in the province.

The temperature is projected to increase by 1.3-1.8^{0}C in the coming 40 years (i.e., by 2045). Likewise, annual precipitation is expected to increase by 8-12 percent. Additionally, seasonal floods and droughts in the Sunkoshi, Tamakoshi, NarayaniDirectives, Bagmati, Marin River Basins due to altered rainfall patterns are likely to create more devastating landslides and wildfires. Consequently, climate and disaster risks are expected to further increase, affecting people and the environment, putting infrastructure, especially roads and drinking water infrastructure development gains at greater risk. Also, rising temperatures and pollution increase respiratory and cardiovascular disease of the people reducing their productivity and active life span.

The main objective of the Guideline is to develop a simple and practical climate resilient infrastructure planning and development directives and tools. The scope of the work includes guiding of planners and engineers to better design and build road and other infrastructures that can withstand extreme weather and climate change-induced hazards. The expected outcomes is that roads, irrigation canals and drinking water facilities remain functional, safe, and durable all the seasons and do not damage settlements, natural and cultural heritage. The Guideline is aligned with the national sustainable development goals/principles, nature/ecosystem-based approaches and solutions and climate resilience building norms, hybrid bio-engineering methods that upgrades traditional bio-engineering tools to Nature-based Solutions (NbS). The aim is to build climate resilient infrastructures in the province. The NbS is one of the fundamental requirements for the resilient infrastructure development and includes: a) Ecosystem-based Adaptation (EbA), b) EcoDRR, and c) Ecosystems Protecting Infrastructure and Society (EPIC) all of which address short and long term risks and hazards, ensuring sustainability and resilience of engineering structures using reinforcement with ecosystem-based measures to make the infrastructure cost effective ion the long-term basis. These approaches also meet MoPID's current and future risk management strategy for both human-induced and natural disasters. Also, the Directives can be applied to all provincial infrastructure projects (roads, bridges, irrigation, housing, schools, hospitals, energy, water supply, health and sanitation related infrastructure).

With key concept and approaches such as systems thinking, pro-active lens, risk-resilience framework, and integrated design and development framework, the Guideline recommends collecting data through both geospatial and socio-ecological mappings deliberately considering historical, biophysical, socio-cultural and projected climate and demographic data and engaging stakeholders through consultative workshops, focus group discussion and expert panels to plan resilient road infrastructures and to actualize risk-resilient society and road development in the province. To complement structurally resilient infrastructures, the guideline supports no and/or low-regret livelihood interventions promoting climate smart agriculture and reducing communities' dependency on single climate-sensitive livelihood such as subsistence agriculture through provision of alternative market oriented livelihood

diversification and payment for ecosystem system services using the fund that is currently paid by the Nepal Road Authority (NRA). The Guideline heavily emphasizes the use of Nature-based Solutions (NbS) to protect and sustainably manage and restore natural or modified ecosystems damaged by road structures and unsustainable agricultural practices. This will address societal challenges effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits. The guideline also strongly recommends including earmarked budget under the provincial road infrastructure budget heads so as to adequately provide technical training to the Engineers and maintenance staff. Also, out of the total revenue collected as road tax and toll, a fixed percentage of the revenue should be allocated to carry out community development activities such as training on linking roads to the development of small and micro enterprise (SME), agri-business development, and market access techniques focused on the road side settlers. This will ensure greater community ownership of the provincial road. The Guideline follows the principle of linking infrastructure to local social and/traditional institutions such as forest users' groups, women's cooperatives, SMEs with clear operation and maintenance roles and equitable benefit sharing with indigenous peoples and local communities, and using infrastructure to reflect local cultural and indigenous practices.

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PART A: CONTEXT, BACKGROUND AND RATIONALE

1 Introduction and Background

1.1 National Climate Context and Background

Nepal is among the world's most climate-vulnerable countries, ranking 69th in the Global Climate Risk Index 2025. Rising temperatures, erratic rainfall, and frequent disasters are reshaping livelihoods, infrastructure, and ecosystems. Bagmati Province, home to Kathmandu Valley, faces compounded risks due to rapid urbanization, fragile mountain terrain, and irregular monsoon cycles (MoFE, 2019; ICIMOD, 2019).

Nepal is enhancing its ability to implement long-term climate adaptation and disaster risk reduction actions based on risk and vulnerability assessment and climate context. The national determined contribution (NDC), long-term strategy for emission reduction (LTS), and national adaptation plan (NAP) documents of the government of Nepal (GoN) establish specific climate action targets that have been included in the 16th national development plans, as well as in subnational and sectoral plans. Nepal has developed its monitoring, reporting, and verification (MRV) system to report on climate progress by the targets set, as well as to increase institutional capacity to monitor and report on climate action.

In order to integrate climate change into the development agenda, it is essential to establish a planning architecture, comprising enabling policy frameworks, as well as supportive institutional and financial arrangements. Nepal has made significant progress in terms of integrating climate change into the national development agenda including the development of the National Adaptation Program of Action (NAPA, 2010), the Climate Change Policy (2019), the Local Adaptation Plans for Action (LAPA framework (2011) as well as National Disaster Risk Management Strategy and Action Plan (2011). In addition, the sectoral plans GoN have also outlined climate priorities. The Climate Change Budget Code (NPC, 2012) in Nepal has enabled the integration of climate change into development planning. In the fiscal year 2082/83, a significant amount of the budget was climate tagged – nearly half of the NPR 1.96 trillion total budget amounts were allocated across multiple ministries. After the country embraced federalized governments, Nepal

developed a series of new legal and institutional mechanisms and policies/strategies to implement a National Adaptation Plan (NAP), the long-term strategy (LTS) as agreed in the Paris Agreement. The Environment Protection Act (2019), Nepal Climate Change Policy (2019),Climate Resilient Planning and Budgeting Directives (2019), Disaster Risk Reduction and Management Act (2017) and Regulations (2019), GESI and Climate Change Strategy and Action Plan (2019), National Reducing Emissions from Deforestation and Forest Degradation (REDD+) Strategy (2018), Sectoral Policies (forestry, energy, industry, transport, agriculture), National Adaptation Plan (NAP, 2021) and the Long Term Strategy (LTS) were the major policy and legal frameworks that are applicable to all three levels of governments (MoFE, 2021). The National Planning Commission (NPC) also developed and released Climate Resilient Planning (CRP) (NPC, 2011) tool in order to initiate climate resilience building process in Nepal. This CRP tool is a strategic, government-led initiative spearheaded by the National Planning Commission (NPC) and the Ministry of Forests and Environment (MoFE) to integrate climate change adaptation (CCA) and disaster risk reduction (DRR) directly into national, provincial, and local development plans. The goal is to move from reactive, short-term measures to proactive, long-term resilience, aligning with the 15th and 16th Periodic Plans. It is a comprehensive framework that integrates climate concerns into development plans and programs. It aims to facilitate ministries, departments, and development organizations in analyzing sector-specific climate issues and adopting measures to reduce emerging and anticipated climate threats. This tool recommends screening development plans and programs for building climate resilience, enhancing climate knowledge and good practices at the implementation level and identifying areas for inter-sectoral cooperation. It is intended to help the Government of Nepal achieve its Nationally Determined Contribution (NDC) and adapt to the impacts of climate change on the long-term basis.

1.2 Policy and Legal Framework

The Articles 11 and 30 of the Environment Protection Act (2076) of Nepal empowers the Gov. of Nepal (GoN) in consultation with the Provincial Government to require supplementary environment impact assessment (EIA) and make other special provision to ensure that road and other infrastructure

development activities do not cause harm to natural and cultural heritages and resources.

The article 30 (1) states: “Government of Nepal may, in consultation with the Provincial Government and concerned Local Level and by a notification in the Nepal Gazette, maintain as an environment protection area any place containing a natural heritage or aesthetic place which is considered extremely significant from the point of view of environmental protection or any place of historical or cultural importance: The Article 30 (2) further states that “In making any road, building, river management or other physical infrastructures, the Government of Nepal may, in coordination with the concerned body and by a notification in the Nepal Gazette, specify any specific area as an open or green area with a view to protecting the environment of such area.” (MoFE, 2019)

Provincial government institutions/agencies have clear roles and responsibilities at different levels, including policy formulation and monitoring and evaluation leading to the implementation of climate change adaptation (CCA) and disaster risk reduction (DRR) related interventions in a direct or indirect manner. In this context, each province is entitled to develop its institutional arrangement within its own structure. All seven provinces have a similar ministerial division, generally assigning climate change related action to the Ministry of environment, forest, and tourism. There are national level climate change-related policies and frameworks that are designed to facilitate the provincial and local level climate actions. The Environment Protection Act, Environment Protection Regulations, Local Government Operation Act, and National Climate Change Policy are the guiding federally enacted laws and policies which have assigned clear role for the provincial and local governments on climate change.

2 Climate Change Scenario, Vulnerability, and Resilience Building Needs

2.1 Climate Context of Nepal and Bagmati Province

Nepal's national average temperature is rising rapidly with distinctly higher warming observed in higher elevations and dense urban settlements (WBG, 2022 ADB, 2025; and DHM, 2024). Average annual temperatures continue to increase, with more frequent heat waves and warmer nights. Bagmati province is one of the most vulnerable provinces to climate change and natural disasters in Nepal and faces both extreme and slow-onset climate-related risks hazards. The province's climate vulnerabilities stem from a combination of fragile mountainous topography and degrading ecosystems, highly variable monsoon-driven hydrology, unplanned especially, urban settlements, and a lack of resilient infrastructure planning, design and development. Recent climatic shocks include the Melamchi Flood Disaster, 2021; Roshikhola Flood Disaster, 2024 and recurring Bhotekoshi landslides. Floods and landslides were the most frequent hazards observed over the past 40 years in the province (Figure 1).

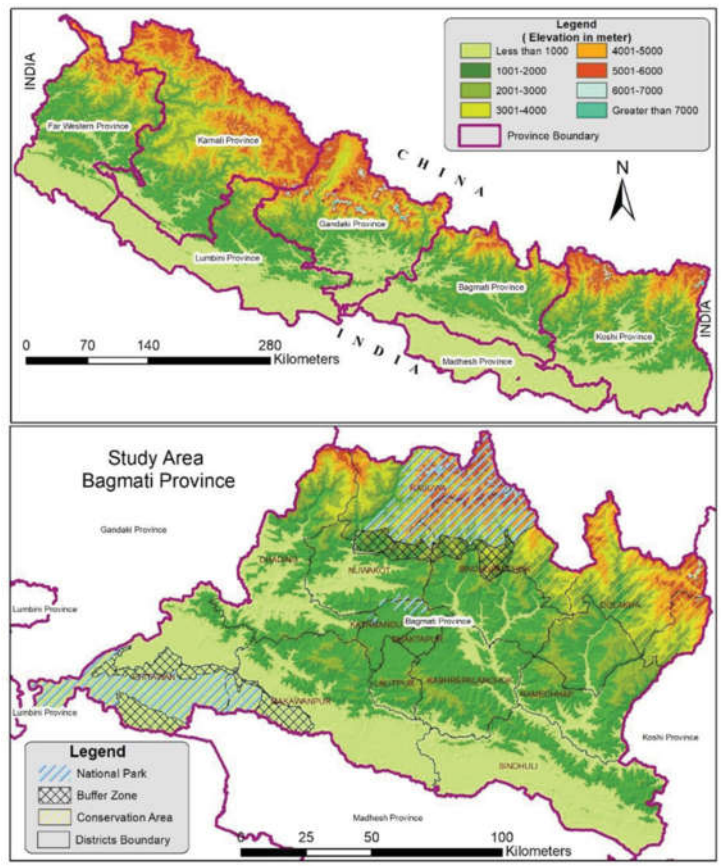


Figure 1: Elevation, administrative and major land use map of Bagmati Province

Temperature is projected to increase by 0.92–1.07^{0}C in the medium term (2016–45) and 1.3–1.8^{0}C in the long term (2036–65) from the reference period of 1981–2010. Likewise, annual precipitation is expected to increase in both the medium and long term by 2–6 percent to 8–12 percent with more precipitation expected in the higher regions. Winters are projected to be drier and monsoon summers wetter, with up to a threefold increase in rainfall. According to the WB and ADB reports (DHM, 2024; MoFE, 2019; ADB, 2025), the number of people in Nepal annually affected by river flooding caused by climate change could more than double to around 350,000 in 2030 (from 157,000 in 2010). At the Bagmati Province level, seasonal extremes are high with winter temperature can drop to -20°C, while summers peak at 36°C, showing sharp variability. Rainfall pattern is irregular with monsoon showing increasingly erratic trend —short, intense downpours alternating with prolonged dry spells (DHM, 2024). The province is fast urbanizing with Kathmandu valley regularly facing flash floods, heat stress, inundation and water scarcity, worsened by unplanned urban growth. Agricultural Impact is high with farmers struggling with disrupted planting cycles and reduced predictability of water availability. Specific impacts of climate change in the province are derived from the following factors:

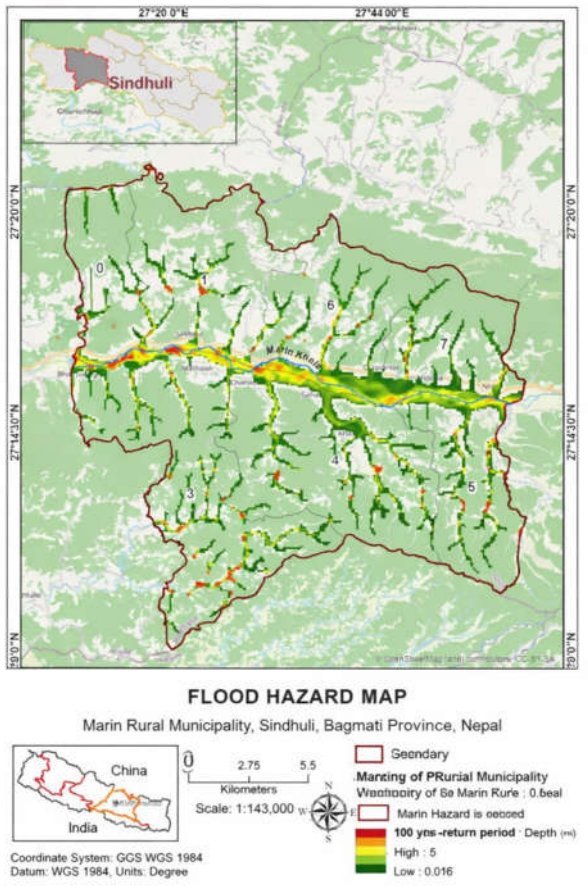


Figure 2: Flood hazard map of Marin Rural Municipality, Sindhuli district

Major Climate Hazards: Both riverine and flash floods and high variability in river discharge are major hazards and risks. Seasonal floods and droughts in the Sunkoshi, Tamakoshi, Narayani, Bagmati, Marin River Basins due to altered rainfall patterns create landslides and wildfires.

Increasing Landslides: Northern hill districts especially Rasuwa, Nuwakot, Dhading, Dolakha and Sindhupalchok face frequent landslides during intense monsoon rains, damaging infrastructure and displacing communities (Wijaya, I. P. K., Towashiraporn, P., Joshi, A., Jayasinghe, S., Dewi, A., & Md. (2023).

Heat Stress and Drought: Rising temperatures and prolonged dry spells affect urban dwellings due to urban heat island (UHI) effect, agriculture, water supply, and public health lowering coping and adaptation capacities.

Air Pollution: Kathmandu valley in recent years has been experiencing worsening air quality, compounding climate-related health risks making the elderly and child population especially vulnerable.

Unequal Coping Capacity: Rural and marginalized groups remain disproportionately vulnerable compared to urban households with better access to resources.

2.2 Increasing Vulnerability and Need for Risk-Informed Resilience Road Development

Mountains are warming faster than the hills and plains, triggering melting of ice and permafrost and an increase in the risk of landslides. Incidences of dry spells, droughts, forest fires, heat waves, flash floods, and disease outbreaks are increasing along with slow-onset risk. Climate and disaster risks are expected to further increase, affecting people and the environment, putting infrastructure development gains at risk (MoFE, 2019). Heavy monsoon floods and landslides in 2021 and 2024 caused hundreds of deaths, displaced thousands of people, and damaged many roads. The number of flood events has doubled in recent years; storms, erosion, and landslides are also on the rise, resulting in loss of life and livelihoods. Heavy monsoon floods and landslides in 2021 and 2024 caused hundreds of deaths, displaced thousands of

people, and damaged many roads (UNDRR, 2021, 2024; MOHA, NDRR Portal-Disaster Reports, 2024).

2.3 Increasing Economic Costs of Climate Change Impacts

The CDKN/IDS-Nepal study (CDKN/IDS-N, 2014) estimated that indirect costs from infrastructure damage could raise the overall economic burden of disasters by 25-100% or more. The study further implied that impact from the climate induced disasters could triple or higher compared to immediate direct damage (CDKN, 2014). This will contribute to further increase in Nepal's relative exposure to climate-related hazards. Warming threatens the future of Nepal's high mountain glaciers, which are a critical supply of freshwater to the region. In Kathmandu, water stress is so severe that piped supply is reported to meet less than 32 percent of household demand in the monsoon and 19 percent in the dry season (UNICEF, 2023).

Lack of climate considerations in the built environment and urban planning exposes cities and major trade corridors—where much of the economy is concentrated—to greater risks. The province's infrastructure is vulnerable to heavy rainfall, flooding, and landslides, the frequencies and intensities of which are increasing. Ninety percent of Nepal's movement of passengers and goods takes places on road transport networks. In FY2019/20, road infrastructure incurred damages worth over NPR 2 billion (US$16.4 million) with Bagmati province suffering the major share of damage. Extreme events such as floods, landslides, droughts, and glacial lake outburst floods (GLOFs) are intensifying (ADB/IDA/SDC, 2025). Economic Losses are mounting. Climate-related disasters cost Nepal about $221 million annually, alongside significant human casualties (ADB, 2025). Over 50 of 77 districts are moderately to highly vulnerable to climate-induced hazards. National policy and legal frameworks emphasize resilience, disaster preparedness, and integration of climate adaptation into development planning.

Nepal especially, Bagmati Province has been urbanizing rapidly, with almost half of the urban population living in informal settlements (CBS, 2021). Projections for 2050 show that the number of municipalities under 'very high' and 'high' risk from climate change impacts will more than double. In particular, the rising risk of glacial lake outburst floods and other types of flash floods pose devastating threats to road infrastructure WB, 2021). While Nepal

cannot fully eliminate its inherent disaster vulnerabilities, investments to manage risks to road infrastructure are vital. Managing the challenges and opportunities brought by increasing disasters triggered by multiple hazards requires effective institutions and governance (ADB, 2021, ICIMOD, 2019).

2.4 Implications of the Increasing Climate Change vulnerability

Figure 3. Overall Climate Vulnerability Map of Bagmati Pradesh, 2026

Although, agriculture, food security and livelihood are impacted the most due to erratic rainfall, drought, flash floods, broken road and irrigation infrastructure that undermines mobility, food, water and health security. Provincial road infrastructures are damaged due to high flooding and landslides due to poor and inadequate drainage, extreme weather systems, and poor water management systems. Bagmati Province's roads are experiencing increasing climate change–induced vulnerabilities and risks, particularly from floods, droughts, landslides, and forest fires. Climatic hazards and risks intersect with rapid road expansion, urbanization, haphazard and fragile infrastructure development, and uneven adaptation and disaster prevention capacities, creating significant risks for both rural and urban populations. Immediate policy action is required to strengthen resilience of the

provincial road system by integrating climate adaptation and DRR into provincial and local governance, and safeguard livelihoods.

2.5 Rationale and Justification of the Directives Development

Experts opine that provincial road infrastructure planning need to align with national climate strategies while tailoring interventions to Bagmati's unique urban–rural mix. They have recommended climate-resilient road infrastructure by expanding flood and water management systems, green drainage, and heat-resilient urban design especially in Kathmandu Valley. It is also necessary to ensure that Bagmati's provincial climate action plans are harmonized with Nepal's national adaptation planks (NAP) and Sustainable Development Goals frameworks especially in provincial road infrastructure. In addition, the infrastructure governance is essential to safeguard both infrastructure and communities promoting sustain development.

Climate resilient road infrastructure design and development guideline for Bagmati Pradesh, especially in provincial roads and bridges is felt necessary to meet the existing legal requirements of the Govt. of Nepal (GoN). The Directives once officially approved, can guide planners and engineers to better design and build provincial roads that can withstand extreme weather and climate change-induced hazards such as heavy rainfall, flash floods, landslides, slope failure due to weak geology, increasing hydro-meteorological extremes, glacial and permafrost melting, extreme weather variability, and soil instability, so that provincial roads remain functional, safe, and durable over time and do not damage settlements, and natural and cultural heritage.

Since purely engineering solutions are costly and are often not aligned with the ecosystem principles and climate resilience norms, bio-engineering methods that are now upgraded to Nature-based Solutions (NbS) are used to build climate resilience especially in provincial road, drainage, drinking water and building infrastructures. NbS according to IUCN "leverage nature and the power of healthy ecosystems to protect people, optimize infrastructure and safeguard a stable and biodiversity rich future". NbS includes a) Ecosystem-based Adaptation (EbA), b) EcoDRR, and Ecosystem Protecting Infrastructure and Communities (EPIC) all of which address short-and long-term risks and damages. NbS ensure sustainability and resilience of engineering structures using ecosystem-based measures to make them more cost effective. It is

tailored and demand-based combinations of both biological and engineering options and is included in this Guideline to meet MoPID's current and future needs and context.

Climate change and weather extreme are increasingly affecting transportation systems most due to rising temperatures including heat waves, extreme rainfall events, flash flooding, inundation, drought, and landslides. Bagmati province being a hilly and mountainous province , its' road networks, which form the backbone of province's economic and social activities, are highly vulnerable to these impacts. Climate-resilient provincial road and other physical infrastructure construction in the province, therefore, refers to the planning, design, materials use, and management practices that improve a road's capacity to withstand, adapt to, and recover from climate-related stresses, impacts and damages as well as inherent geo-physical hazards and risks in a more cost-effective manner. The climate resilience in road infrastructure design and construction should ensure the following aspects:

- Long-term cost savings
- Year-round accessibility and usability
- Greater safety for travelers and users
- Reduced disaster-related repair needs and costs

3 Purpose, Scope and Objectives:

3.1 Purpose and Scope

The purpose is to ensure mainstreaming and integrating climate and disaster resilience considerations, factors and imperatives in planning, designing and construction of the road infrastructure in Bagmati Province. The scope of the work is to specify norms, standards and procedures that are applicable to infrastructure, especially roads and drinking water facilities funded, executed and maintained by provincial government. The Directives can be applied to all provincial road and related infrastructure projects.

3.2 Objectives

The main objective of the Guideline is to develop a simple and practical provincial climate resilient road infrastructure planning and development

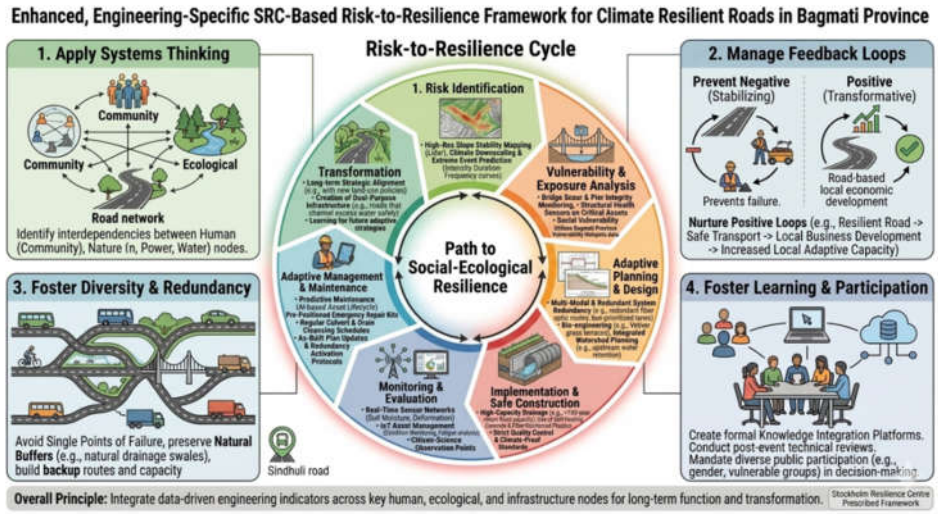
directives that enable engineers, planners, and decision-makers of the Bagmati province to:

- Identify current and future climate risks and vulnerabilities while planning and constructing provincial road infrastructure.
- Integrate resilience into planning, design, construction and maintenance specifying climate-resilient design standards, feasible technologies, and best practices.
- Provide actionable standards and workflows to plan, design, build, operate, and finance climate-resilient physical infrastructure in mountainous terrain.
- Guide investment decisions to be resilient, sustainable, and cost-effective.
- Strengthen institutional capacity (technical, human and systemic) so that agencies and professionals are better equipped to plan, design, and manage climate-smart infrastructure.
- Establish actionable standards for planning, design, construction, and maintenance of climate-resilient road infrastructure in hilly and mountainous terrain.
- Ensure resilience against landslides, floods, and extreme precipitation aligning with Nepal's National Adaptation Plan (NAP), National Disaster Risk Reduction Strategies (NDRRS) and Bagmati province's development priorities.

4 Principles, Approach and Methodology

4.1 Principles of Climate Resilient Infrastructure

The principles are mainly focused on road design, construction and maintenance aspects. However, overarching principle applied is risk-informed planning based



(Stockholm Resilience Centre, 2026)

Figure 4: Risk to Resilience Framework

on the Risk-to-Resilience framework and strategy (RRFS) (Fig. 4). The RRF uses the adaptation and transformation stages to highlight Nepal's disaster response and systemic reforms. It emphasizes the nested circles to show how Bagmati's economy and society rely on ecological resilience. The visual progression (risk → resilience) can be tailored with local icons (e.g., floods, landslides, community cooperatives).

If the climate resilient infrastructure is not designed, constructed and maintained using system-based framework such as RRF using risk-informed and inclusive planning concept, there will always be chances to experience unpredictable losses and damage of road infrastructure during heavy to extreme rainfall events especially in fragile Churia and Midhill regions. Currently the province's primary and secondary roads are regularly blocked due to landslides, defects in pavement layers as a result of temperature stress, which reduces accessibility during monsoon and increases the maintenance cost and reconstruction delays. Therefore, it is critical to ensure climate-

resilient road construction that can survive landslides, heavy rains, floods, erosion, and temperature extremes, using smart bio-engineering technologies including nature-based solutions (NbS) that include all weather drainage, slope protection, and low-emission construction materials. Climate resilient roads should follow the following principles:

Hazard-Responsive and risk-based Planning: Road infrastructure design should be informed by local hazard profiles—earthquake zones, flood plains, landslide-prone slopes that can be achieved by using multi-hazard risk assessments and mapping during site selection and planning. It is necessary to conduct hazard mapping and vulnerability assessments to identify high-risk areas, Care should be taken to avoid building in high-risk zones unless absolutely necessary and apply extra mitigation measures if assessed so.

Structural Robustness and Redundancy: It should be ensured that road, drainage and bridge infrastructure can absorb shocks without collapsing the use of redundant systems (e.g., multiple drainage paths, backup power) to maintain functionality during crises. The engineers should apply performance-based design—structures that not only meet minimum codes but perform under extreme conditions.

Climate Change Adaptation: The engineers should incorporate climate-resilient materials (e.g., corrosion-resistant steel, permeable pavements) by designing for temperature extremes, heavy rainfall, and droughts. They should include green infrastructure like bio swales, rain gardens, and vegetated buffers to manage storm water and heat.

Modularity and Flexibility: Use of modular components that can be easily repaired or replaced should be considered while designing infrastructure that can be upgraded as technology and needs evolve. For this build infrastructure for flexible and multiple use e.g., schools that can serve as shelters during disasters.

Community-Centric and Inclusive Design: Engaging local communities in the design process can ensure relevance and ownership as well as make infrastructure accessible to all, including persons with disabilities, elderly, and children. Also, reflecting local culture and traditional knowledge in design choices can enhance ownership by all users.

Environmental Integration: Minimizing ecological disruption by preserving natural drainage, vegetation, and wildlife corridors and using low-impact development (LID) techniques to harmonize built and natural environments can enhance climate resilience. Also promoting energy efficiency and low-carbon construction practices build resilience.

Lifecycle Resilience: Climate resilient infrastructure building considers long-term durability and maintenance needs from the outset. It includes design for easy inspection, repair, and retrofitting and uses materials and systems with proven resilience in similar geographic and climatic conditions.

Knowledge and Data-Driven and Smart Design: Climate resilience needs to be driven by the latest and best modern and indigenous science. Including early warning systems, sensors, and smart technologies for flood defense and real-time data-based monitoring should be possible by using GIS and BIM tools for planning, simulation, and risk visualization. Also enabling digital documentation for maintenance and disaster response will save time and build institutional memory.

4.2 Approach and Methodology for Climate Resilient Infrastructure

4.2.1 Approach:

The general approach for developing guideline for resilient infrastructure design is based on the principle of creating infrastructure that can withstand, adapt to, and recover from climatic shocks and stresses—especially in a region like Bagmati Province, Nepal, which faces increasing frequency and ferocity of climate change and weather variability related risks like landslides, floods, forest fires and glacier and permafrost melting. We specifically use a UNDRR prescribed Risk to Resilience (R2R) framework “which is a strategic approach that moves beyond just managing risks to actively building the capacity (resilience) to withstand, adapt, and positively transform from disruptions, using systemic thinking to connect threats (risks) with the ability to recover, ensuring long-term stability and goal achievement, often integrating risk analysis with proactive development strategies” (UNDRR, 2019). It uses structured blueprints (frameworks) to identify risks (hazards, failures, etc.) and then develop actions to increase an entity's (individual, community, organization) capacity to absorb impacts and recover effectively, often by strengthening systems, processes, and capabilities.

The key concepts & approaches are a) *Systems Thinking*: Viewing interconnected elements (people, processes, systems, environment) to understand how risks cascade and where interventions have the most impact, b) *Proactive Lens:* Shifting from reactive crisis management to proactively building resilience to prevent setbacks and foster positive change, c) *Risk-Resilience Equation:* Understanding risk as a function of hazard, exposure, and vulnerability, but incorporating resilience as a key factor that modifies the outcome, often framed as: $Risk = Hazard \times Exposure / Resilience$; d) *Integrated Frameworks*: Combining risk management (identification, assessment, mitigation) with resilience building (adaptation, recovery, transformation) into one cohesive strategy, as seen in the UN's approach to Sustainable Development.

4.2.2 Methodology

Data Collection and Analysis: This will involve a) Climate Risk Assessment wherein collecting historical and projected climate date (temperature, rainfall, floods, landslides, droughts), b) geospatial mapping - applying participatory GIS to identify hazard-prone areas and critical infrastructure; c) Socio-Economic Profiling - assessing community vulnerability, livelihood dependencies, and service accessibility; d) Engineering Surveys - conducting soil, hydrological, and structural assessments for roads, water systems, and buildings; e) Policy Review - aligning with national building codes, provincial regulations, and international resilience standards.

Stakeholder Engagement: This component will include a) Consultative Workshops: Involve provincial ministries, municipalities, engineers, and community representatives; b) Focus Group Discussions: Capture local knowledge on climate impacts and coping strategies; c) Expert Panels: Validate technical designs with academia, professional associations, and donor agencies; d) Feedback Loops: Ensure iterative refinement of designs based on stakeholder input.

Design and Development Process: This component will include: a) Risk-Informed Planning: Integrate hazard maps and vulnerability data into site selection and design; b) Resilient Engineering Standards: Apply climate-adaptive materials, drainage systems, slope stabilization, and energy-efficient designs; c) Scenario Testing: Model infrastructure performance under different

climate scenarios (e.g., extreme rainfall, heat waves); d) Cost-Benefit Analysis: Compare traditional vs. resilient designs to justify investment and f) Compliance Framework: Ensure designs meet provincial Directives, MoPID directives, and national codes.

Implementation and Monitoring: The methodologies should be pre-tested in selected municipalities before scaling province-wide for which institutional and technical capacity building programme has to be launched by training engineers, planners, and local officials. In order to ensure maximum compliance robust monitoring tools have to be used with digital dashboards for compliance, performance, and maintenance. MOPID has to also use Evaluation Metrics to measure resilience outcomes (service continuity, safety, cost savings). District engineers have to be trained in following adaptive management by periodically revising Directives based on lessons learned and evolving climate data.

Documentation and Knowledge Sharing: Guideline provides detail Annexes that contain technical specifications, checklists, and templates especially focusing on road construction. Case Studies should be undertaken by the provincial agencies and academic institutions to document successful resilient infrastructure projects in Bagmati Province. The MOPID website should set up Knowledge Platforms to share case study findings through provincial portals, workshops, and academic publications. Scaling-up and scaling-out pathways for replicating and scaling the successful solutions to other provinces and sectors are useful.

PART B. DETAILED GUIDELINE

5 Guideline Structure, Standards and Process

5.1 Context and Applicability of Guideline

In accordance with the constitutional and legal mandates of the Government of Nepal and recognizing the urgent need to safeguard Bagmati Province against climate-induced hazards and risks, earthquakes, floods, landslides, and forest fires, the Ministry of Physical Infrastructure Development (MoPID), GoBP has prepared the "Resilient Physical Infrastructure Development Directives, 2026". The Directives, together with their Annexes, Implementation Circular, Compliance Report format, Provincial Dashboard framework, and Digital Workflow, provide a comprehensive package to: a) Integrate resilience into planning, design, construction, and maintenance of infrastructure projects, b) Establish clear institutional responsibilities and monitoring mechanisms, c) Ensure financial allocation and accountability for resilience measures, and d) Promote transparency through public dashboards and community engagement.

The Guideline has been designed to be locally relevant, operationally practical, and aligned with national and provincial priorities including the Sustainable Development Goals (SDGs), the National Adaptation Plan (NAP), and the Disaster Risk Reduction and Management Act (2017). The Directives primarily guide the infrastructure planners, developers and practitioners how to plan, design and build climate resilient infrastructure using resilient design and development principles. The principles described above could be applied to a specific type of infrastructure—like roads, bridges, or public buildings in Bagmati Province. However, the main focus of this guideline is on its primary use for designing and developing roads, bridges and urban buildings. A tailored breakdown of how resilient design principles are provided specifically to roads, bridges, and urban buildings in Bagmati Province, Nepal-where climate and weather extreme events, seismic activity, landslides, floods, and rapid urbanization pose serious challenges. The major components of the Guideline are as follows:

5.2 Application Procedure of the Guideline

- This guideline applies to all provincial infrastructure projects (roads, bridges, irrigation, housing, schools, hospitals, energy, water supply, and sanitation).
- This covers both new construction and retrofitting projects.

5.3 Guideline Implementation Process

- Planning: Conduct multi-hazard mapping, vulnerability impact assessment, and resilience criteria analysis in infrastructure feasibility studies.
- Design: flood-resilient/proof, landslide mitigation, rehabilitation with eco-friendly materials.
- Construction: Maintain compliance with the National Building Code, community monitoring, and auditing norms.
- Operation & Maintenance: Ensure annual inspections, retrofitting, and dedicated maintenance funds.

6 Directives for Resilient Road Infrastructure Design and Development

6.1 Climate Adaptive Road Design and Development

6.1.1 Planning and Design

Climate change is affecting both the physical nature of road infrastructure and the level and quality of service. Climate change is a risk multiplier; therefore, proper and effective risk-reduction measures need to be incorporated during the construction phase. Based on the existing Directives on Design, Construction and Maintenance of Road Infrastructure incorporating Climate-resilient Features (2019), the following points can be suggested to build climate resilience in road construction phase:

- To enhance climate resilience, special emphasis should be made on hydrological risk analysis and geotechnical studies, to account for higher rainfall intensity due to climate change; cross-drainage outlets should include cascading structures to prevent scouring in Bagmati Province.
- As far as possible, all excavation should be carried out during dry weather.

- During construction, environmental management plans should be prepared and approved to prevent and mitigate environmental hazards.
- Special emphasis on and provision for bio-engineering methods and nature-based solutions (NbS) must be given.
- In order to address climate change impacts, side slope should be adjusted as per the standard gradient for Cut/Fill slope according to soil classification defined in Guide to Road Slope Protection Works published by Department of Roads (2003), to prevent flood damage and erosion from road surface runoff wherever possible. The typical cutting with berms is given in Figure 5 and typical filling slope with berms is given in Figure 6.

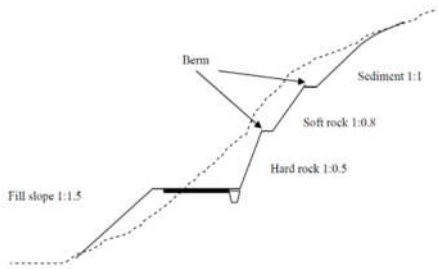


Figure 5: Typical cutting slope with Berms

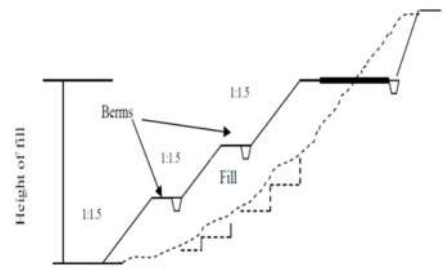


Figure 6: Typical fill slope with Berms

6.1.2 Route Selection & Geometric Design

- Route alignment and geometric design should follow natural contours to minimize cutting and filling, prioritize ridge alignments over valley sides where feasible, and avoid landslide-prone areas and debris-flow channels to reduce climate-induced hazard risks.
- Road alignment and route selection for climate-resilient infrastructure should prioritize minimizing exposure to climate-induced hazards while ensuring long-term safety, durability, and serviceability.
- Route selection should also consider future climate scenarios by allowing adequate drainage, reducing maintenance needs, protecting nearby communities and livelihoods, and ensuring safe access during extreme weather events.

- Climate resilience should be integrated by considering future rainfall intensity, flooding, and temperature variations. Adequate space for drainage, slope protection, and flood conveyance should be provided to reduce damage during heavy rainfall.
- From a climate-resilience perspective, steep gradients (>7%) shall be avoided where possible, with grade compensation applied in accordance with Nepal Road Standards 2070; longitudinal gradients shall be eased at higher elevations and on curves to improve drainage, safety, and road performance under extreme weather conditions.

6.2 Guideline for Climate Resilient Road Construction

Constructing resilient roads in hilly and mountainous terrain requires addressing steep gradients, unstable slopes, intense rainfall, erosion, landslides, seismic activity, and difficult construction access. (see Annex 1 for detailed toolkit and Directives)

6.2.1 Slope Stability & Earthworks

- In a climate-resilient approach, cut and fill materials and slope heights should be designed as per Nepal Road Standards 2070, with required benching and immediate slope protection to prevent erosion and soil movement under heavy rainfall and extreme weather conditions.
- For climate resilience, conduct geotechnical surveys to assess slope stability and provide suitable retaining structures with proper drainage based on soil type and slope height.
- Slope stability measures for climate-resilient roads should include proper slope geometry, effective drainage, vegetation, and protective or retaining structures to withstand increased rainfall and reduce landslide and erosion risks.
- Climate-resilient earthworks should use well-compacted, durable materials with adequate drainage and erosion control to handle higher runoff and extreme weather, ensuring long-term road stability and performance.

6.2.2 Drainage and Water Management

- The minimum longitudinal gradient of 0.5% should be provided to ensure effective drainage. Catch-water drains should be installed above

cut slopes in landslide-prone areas to control runoff, as unlined drains are a major cause of road failure in hilly and mountainous regions.

- To enhance climate resilience in landslide-prone areas, essential measures like horizontal drains, gabion breast walls, and bio-engineered slope stabilization and water-management structures to reduce climate-induced landslide risks should be included.
- For climate adaptation, hydrological design parameters shall be derived using updated climate projections and adjusted rainfall intensity values. Adequate freeboard shall be incorporated in the design of bridges and culverts to accommodate changes in flow and associated uncertainty. Inadequate drainage is a major cause of structural failure during monsoon season, proper channel lining and toe protection should be provided to prevent waterlogging and scouring of bridge foundations and road embankments, thereby improving climate resilience.

6.3 Directives for Retaining and Road Protection Structures

- Application of gabion walls for retaining and breast walls is more advantage due to its flexibility in nature which can deform or adapt to ground movement (such as soil settlement or seismic activity) without cracking or losing their structural integrity.
- Gabion retaining walls enhance the climate resilience of roads by providing flexible, permeable, and durable slope stabilization and erosion control, which helps infrastructure withstand extreme weather events like intense rainfall, flooding, and landslides in Bagmati Province.
- A toe wall is a low-height retaining structure constructed at the base (toe) of an earthen slope or embankment. Its use in climate-resilient roads is critical for preventing scouring, erosion, and soil movement, thereby protecting the structural integrity of the road foundation against intense rainfall, flooding, and landslides. Plan for regular inspection and maintenance of infrastructure, especially after monsoon events, to ensure early detection and repair of damage of any structure.

6.3.1 Spoil Disposal/Tipping Site

- Disposal of surplus construction materials, cut materials, drainage-cleaning debris, and landslide debris should be carried out as required,

while excavated spoil materials should be classified into reusable material, rock, and unsuitable material.

- Suitable spoils should be reused for embankments and subgrade works, while rock spoils should be recycled for riprap, gabions, and drainage layers.
- All spoil stockpiles should be stored away from watercourses with stable slopes and provided with adequate drainage, covering, and dust control measures.
- Spoil disposal areas should be rehabilitated and stabilized with vegetation, as excessive slope loading from improper spoil disposal can lead to landslides during the operation phase.

6.3.2 Climate friendly management of Borrow Pits

- To strengthen climate resilience, excavated earthworks quantities should be balanced to reduce the need for borrow pits area. The borrow pit area locations should be clearly defined by chainage and required quantity. It should be established away from flood-prone areas, water bodies, and the roadway to minimize erosion and hazard risks.
- Excavation should be carried out with gentle side slopes and controlled depth to ensure stability and safety, with proper drainage provided to prevent water accumulation and erosion.
- To enhance climate resilience, environmental protection measures should be applied during borrow pit operations, and after use, pits should be rehabilitated through backfilling, regarding, and vegetation to restore natural landforms, reduce erosion, and prevent climate-induced degradation.
- To support climate resilience and road safety, no borrow pits should be constructed near the roadside, as such locations increase erosion, instability, and hazard risks to road users, especially during extreme weather events.

6.3.3 Climate friendly management of quarry sites

- Environmental Management Guideline (1999) published by the Department of Roads is outdated and needs to be updated using the relevant clauses of this Guideline.

- Using the above Directives, the quarry sites should be away from population centers, drinking water tank/supply, cultivation land, schools and bridge sites.
- Mention the location with chainage and describe the site condition, amount to be extracted. Ensure the approved IEE of the quarry site.
- Identify current and future risks (flooding, landslides, erosion) and integrate them into road design and material selection.
- Ensure quarry access roads and haul routes are well-drained and usable during extreme rainfall.
- Maintain buffer zones from rivers, settlements, and ecosystems; comply with EIA requirements.
- Design post-quarry restoration to stabilize slopes, control runoff, and restore vegetation.

7 Application of Nature-based Solutions in Climate Resilient Infrastructures

Overview: This section of the guideline provides a framework for integrating Nature-based Solutions (NbS) into provincial infrastructure development to enhance climate resilience, reduce disaster risks, and promote sustainable development without affecting local livelihoods in Bagmati Pradesh. Nature-based Solutions leverage nature and the power of healthy ecosystems to protect people, optimize infrastructure and safeguard a stable and biodiverse future (IUCN, 2020). (Figure 7).

Figure 7: Infrastructure specific application of NbS.

NBS is an ecosystem-based approach that is applicable to all infrastructure projects, especially roads under the Ministry of Physical Infrastructure Development (MoPID), Bagmati province. NbS has five steps in its

implementation. They are: i) defining the stakeholders and their ecosystem area and developing the relationship between them; ii) ecosystem structure, function and management characterizing them and setting in place mechanisms to manage and monitor it; iii) identifying the important economic issues and what will affect the ecosystems and its inhabitants; iv) Developing adaptive management over space and determining the likely impact of the road infrastructure on adjacent ecosystems; v) deciding on long term goals, and flexible ways of reaching the goals.

7.1.1 Roads

Slope Stabilization: Mandate bio-engineering techniques (Vetiver and other grass native species, Amrisho (Broom grass, bamboo and Nigalo species, shrub species.) for roadside slope protection.

Drainage Management: Incorporate vegetated drainage channels, vegetated check dams, and permeable surfaces to reduce flash floods.

Green Corridors: Require tree planting along roads to mitigate heat stress and provide windbreaks well aligned with the geometric design of the road. The plantation should have at least 20 meter gaps wherever possible to avoid disasters caused by tree-felling by wind, landslides and floods.

7.1.2 Irrigation Canals

Riparian Buffers*:* Establish vegetation strips along canal banks to prevent erosion.

Wetland Integration: Promote constructed wetlands at canal outlets for water filtration and recharge.

Agroforestry Linkages: Encourage integration of tree crops and farming along canals to reduce evaporation and diversify farmer income.

7.1.3 Drinking Water Infrastructure

Watershed Restoration*:* Implement reforestation and soil conservation activities in catchments to secure water sources.

Spring Revival: Apply bio-engineering technique in recharge zones to sustain springs.

Green Storage Systems: Use vegetated ponds and infiltration trenches for rainwater storage.

7.2 Key Resilience Building Measures: Adaptation and DRR

- Slope Stabilization: Use retaining walls, bioengineering (e.g., vetiver and native grasses), and geotextiles to prevent landslides.
- Drainage Design: Incorporate cross-drainage structures, culverts, and side drains to manage monsoon runoff and reduce erosion.
- Regulated sand and debris excavation: Regular cleaning of deposited sand and debris from rivers (mainly in valley and plain land) to avoid river overflow, inundation and flood, especially during monsoon.
- Flexible Pavement Materials: Use materials that can withstand temperature fluctuations and waterlogging.
- Redundant Access Routes: Plan alternate routes for emergency access in case of road failure.
- Climate-Proof Surfacing: Apply sealants or surface treatments to reduce damage from intense rainfall and UV exposure.

7.2.1 Resilient infrastructure for resilient local livelihood

Nepal's NAP explicitly calls for integrating community-based DRR, indigenous and local knowledge and livelihood improvement measures into infrastructure adaptation planning. The following policy options facilitate to actualize them;

- Design jointly *with* concerned communities by combining traditional practices, especially nature-based techniques such as vegetative plantation (with engineering knowledge
- Include youth, women, marginalized and elderly people in decision making
- Identify and support no and/or low-regret livelihood interventions that complement resilience infrastructure building, encompassing climate-smart agriculture (flood/drought-tolerant food crops, improved seed banks, agroforestry plantations, non-timber forest products, value-chain support for local crafts, community tourism (homestays, ecotourism).
- If needed, support local communities impacted by infrastructure development by reducing their dependency on single climate-sensitive

livelihood earning especially agriculture and compensate with either alternative livelihood diversification or payment for ecosystem system services.

- Provide technical training especially on small and micro enterprise (SME) business development, and market access techniques in infrastructure project budgets (e.g., establishment of small enterprise facilities — refrigeration, processing, packaging for agroforestry products to reach markets)
- Link infrastructure to local social and/traditional institutions such as forest users' groups, cooperatives, SMEs with clear operation and maintenance roles and equitable benefit sharing.
- Use infrastructure to reflect local cultural and indigenous practices (e.g., in the form of improved infrastructure designing)

7.3 NbS Implementation Mechanisms

- NbS must be embedded into MoPID circulars, Directives, and project approval processes; Training programs for engineers, local governments, and communities on NbS techniques should be regularly conducted.
- Financing: Mobilization of climate funds, donor support and community contributions for NbS projects.
- Monitoring & Evaluation: Establish NbS indicators (erosion reduction, water yield, biodiversity gains) in provincial dashboards. Forming watershed-level User Group participated M&E mechanisms, including concerned ward committees to customize NbS.
- Scaling Up: Pilot NbS projects in high-risk districts such as Sindhupalchok, Dolakha, Makwanpur first and replicate province-wide depending on the success and local ownership.

7.4 Compliance and Reporting on NbS

- Mandatory Compliance: All infrastructure projects must demonstrate NbS integration in design and implementation.
- Annual Reporting: MoPID to publish annual reports on NbS adoption, effectiveness, and lessons learned.

- Audit Mechanism: Independent audits to verify NbS compliance and performance.

7.5 Ensuring Cross-Cutting Benefits/Co-benefits

- Disaster risk reduction: one of the main benefits of NbS is preventing hazards and risks from turning into disasters. NbS are no-regret, low-regret DRR options as it is based on ecosystem management principles.

7.6 Creating database on Loss & Damages

- Develop a database of infrastructure damages and losses exacerbated by climate insensitive infrastructure design and execution.
- Ensure recording all the losses and damages caused by various disasters exacerbated by climate insensitive infrastructure planning and design which can be strong basis for future climate finance negotiations at national and international levels, leading to enhanced budget among affected Paalikas and Wards (see Annex 3 for the Table).

8 Maintenance of Climate Resilient Provincial Road

To make sure money spent on roads is used well and supports long-term development, planners need to consider the current and projected impacts of climate change. Roads are especially vulnerable to higher temperatures, heavier rainfall, and flooding – both flash floods and riverine floods. Climate-induced stress, strain, and damage will cause roads to wear out faster, meaning they will need more frequent maintenance and repairs.

8.1 Types of Climate Resilient Maintenance

8.1.1 Routine Maintenance Aligned to Local Climate Change Trend

- Timing of the maintenance in all the seasons and on all roads should be timed as per the weather forecast made by the DHM/GoN.
- Heavy to extreme rains in the upstream catchment area as well as locally, should be avoided timing maintenance before to reduce disaster risk and after to quickly restore road operation, focusing on cleaning and clearing road blocking elements.
- Ensure to maintain all-weather functioning of the road properly while preventing and/or reducing loss and damage of the asset by regularly

assessing hazards and risks – in upper and lower parts of the alignment – and performing preventive maintenance activities.

- Road maintenance workers should be trained in climate change adaptive maintenance work activities.

8.1.2 Climate Adaptive Recurrent Maintenance

- Recurrent maintenance should also be carried out, considering the local weather variability and weather forecast information issued by the DHM/GoN on all roads
- The repair works should focus on minimizing hazards point to avoid major damage caused by sudden rainfall and flash floods; Signage and warning marks for unstable rock-fall points should also be repaired.
- The aim is to maintain, avoid damage and deluge and restore the road to proper condition especially during rainy season.

8.1.3 Climatic Disaster Risk Reducing Periodic Maintenance

- The main purpose of the periodic maintenance should be to preserve the structural strength of the road.
- Focus should be on renewing and reinforcing the road surface strength and repairing long stretches of road if reducing the hydrological disaster risks so demand.
- Remove medium- or large-scale landslides and landslide protection works.
- Regulated sand and debris excavation from rivers to avoid river overflow, inundation and flood, especially during the monsoon.
- Improve or reconstruct roadside guard walls, parapets, and bridge/culvert railings
- Construct river training (river control) structures even if the rivers and rivulets are small in the Chure region.
- Repair, improve, and rehabilitate retaining walls made of dry-stone masonry, brick masonry, or gabions
- Plant trees, shrubs, vines, grass, and other suitable vegetation along both sides of the road in consultation with and participation of local community
- Repair should be tailored to the nature of roads - earthen, gravel, or black-topped pavements.

8.1.4 Emergency Maintenance

- Emergency maintenance includes work carried out due to sudden and unexpected road blockages due to weather extremes, such as hydrological or natural disasters.
- The main aim is to quickly rehabilitate and operationalize the road, restoring vehicle movement as soon as possible but making sure that the maintenance has enough cushion for similar future events and also protect the road from further damage.

8.1.5 Preventive Maintenance

- Preventive maintenance should aim to avoid the need for major repairs and rehabilitation during the rainy season.
- These works should be done as per the technical requirements of geological, geographical, and environmental factors
- During the rainy season, the work should be carried out as soon as the need is identified by making use of the contingency resources
- Preventive maintenance should include the following activities
    - ✓ Slope cutting and stabilization of roads.
    - ✓ Maintenance of river training work.
    - ✓ Removal of hanging rocks and unstable slopes.
    - ✓ Bio-engineering work and their maintenance.
    - ✓ Regulated sand and debris cleaning from rivers in the valley and plain land

8.1.6 Resilience Building Maintenance Work

- Maintenance of the road and other infrastructure should be carried out with the objective of keeping the road open and an all-weather road throughout the year.
- Maintenance or improvement works along both sides of the road should help prevent potential landslides or slope failures.
- Maintenance should reduce the cost incurred by road users while using the road.
- Road safety works should adopt practical and affordable risk management measures.

- The road should be maintained at its designated service level. Service level refers to the required physical condition and traffic-carrying capacity of the road.

8.2 Implementation Guide for Climate Resilient Maintenance

- Policy Integration: Embed and mainstream NbS into provincial infrastructure Directives and MoPID circulars.
- Capacity Building: Train engineers, local governments, and communities in bio-engineering techniques.
- Financing Mechanisms: Leverage climate funds, donor support, and community contributions.
- Monitoring & Evaluation: Develop NbS indicators within provincial dashboards (erosion reduction, water yield, biodiversity gains).
- Scaling Up: Pilot projects in high-risk districts (Sindhupalchok, Dolakha, Makwanpur) and replicate across the province.

9 Institutional Arrangements for Capacity Building

- Lead Agency: MoPID, Physical Infrastructure Development Directorate, Bagmati Province.
- Coordination: With MoFE, Department of Urban Development, NDDRNA/MOHA.
- Local Governments: For the effective enforcement of the guideline, coordination and cooperation with the municipal level government is necessary.
- Roles and responsibilities of provincial ministries, departments, provincial/local government agencies.
- Coordination mechanisms among agencies

Example: a) Lead Agency: MoPID Bagmati Province; b) Coordination: With MoFE, Department of Urban Development, DRR agencies; and c) Local Governments: Enforcement at municipal level.

10 Monitoring, Evaluation, and Reporting

- Establish resilience indicators.
- Record Loss & Damages associated with infrastructure development
- Annual resilience audit by MoPID.

- Public disclosure of compliance reports.
- Indicators for compliance and performance
- Reporting frequency and responsible authority
- Implementation of resilience measures for road infrastructure
- Evaluate performance of roads during climate events
- Improve future policies and design based on experience

Example: a) Establish resilience indicators; b) Annual resilience audit by MoPID; c) Public disclosure of compliance reports.

11 Financial Provisions for Guideline implementation

The responsibility for construction and maintenance of roads and road bridges identified by the Provincial Road Transport Master Plan lies with the Provincial Government. The following are funding sources for climate resilience building of roads and other infrastructure should be tapped:

- Grants from the Central and Provincial Governments
- Vehicle operation fee (Toll tax)
- Funds provided by development partners
- Funds received from the Nepal Road Board

The Provincial Government shall maintain records of projects constructed through user committees. If maintenance is required on such roads, resources shall be mobilized by the local beneficiary community to carry out the maintenance works.

- Dedicated resilience budget line.
- Access to climate finance and DRR/Resilience building funds.
- Incentives for innovative resilience practices to municipalities and private contractors.
- Budgetary sources, fund flow mechanisms, and accountability measures

Example: **Dedicated resilience budget line**; Access to climate finance and DRR funds; Incentives for innovative resilience practices.

12 Grievance Redress and Compliance

- Mechanism for community complaints.

- Penalties for non-compliant contractors.
- Appeals through MoPID.

13 Climate Resilient Road Infrastructure – Indicator Matrix

The Climate Resilient Road Infrastructure Indicator Matrix provides a structured framework to assess how well road projects incorporate climate resilience consideration. By using these indicators, implementation can be systematically monitored, road performance under climate stress can be evaluated, and decision-making can be supported to improve the durability, safety, and reliability of road infrastructure. The Climate Resilient Road Infrastructure Indicator Matrix is presented in Table 1.

Table 1: Climate Resilient Road Infrastructure – Indicator Matrix

Indicator	Unit	Data Source	Frequency
A. Climate Risk Integration			
Percent of road projects with Climate Risk & Vulnerability Assessment	%	Project reports, feasibility studies	Annual
Number of climate hazards considered in design (flood, landslide, heat, etc.)	Count	Design documents	Per project
Use of updated climate data	Yes/No	Design reports, hydrological studies	Per project
B. Drainage & Hydrological Design			
Design return period for drainage structures	Years	Design reports	Per project
Percent of road length with adequate cross-drainage structures	%	Design drawings, site verification	Annual
Drainage capacity vs projected peak runoff	% adequacy	Hydrological analysis reports	Per project
Frequency of drainage blockage incidents	Event/ year	Maintenance records	Quarterly
C. Slope Stability & Landslide Management			
Percent of road length with	%	Site inspection	Annual

Indicator	Unit	Data Source	Frequency
slope stabilization measures		reports	
Landslide occurrence along road corridor	Event/km/ year	Maintenance logs, disaster records	Annual
Use of bioengineering techniques for slope protection	% of treated area	Project reports, field surveys	Annual
D. Pavement & Structural Resilience			
Use of climate-resilient pavement materials	Yes/ No or %	Design specification, BoQ	Per project
Road damage after extreme weather events	% of road length affected	Field reports, maintenance data	After major events
E. Nature-Based Solutions			
Percent of roadside with bioengineering/green stabilization	%	Field surveys, project reports	Annual
Reduction in surface water flow due to vegetation	%	Hydrological assessment	Annual
F. Construction Quality & Compliance			
Percent of projects complying with resilient design standards	%	Audit reports, supervision records	Annual
Frequency of construction quality inspections	No./year	Supervision logs	Quarterly
Use of locally suitable climate-adapted materials	Yes/No If yes, Estimated %	Project documentation	Per project
G. Operation & Maintenance			
Frequency of drainage cleaning	Times/year	Maintenance logs	Quarterly
Percent of road network under routine maintenance plan	%	Road agency records	Annual
Maintenance budget allocated for resilience	% of total budget	Financial reports	Annual

Indicator	Unit	Data Source	Frequency
Time taken to clear road blockages (landslides, floods)	Hours/ Days	Emergency response logs	After events
H. Performance & Serviceability			
Road closure days due to climate events	Days/ year	Traffic police, road authority records	Annual
Average recovery time after extreme events	Hours/ Days	Maintenance/ emergency reports	After events
Reduction in climate-related damage over time	% change	Historical maintenance data	Annual
Road serviceability (all-weather access)	% of time operational	Traffic & monitoring data	Annual
I. Social & Accessibility			
Population with access to all-weather roads	%	Census, transport surveys	Annual
Number of communities cut off during extreme events	Count	Local government, disaster reports	After events
J. Institutional & Capacity			
Research based on climate-resilient road	Yes/No	Academic/Researcher	Annual
Percent of engineers trained in resilient road design and supervision	%	Training records	Annual
Integration of resilience criteria in procurement	Yes/No	Tender documents	Annual

Note: The Climate Resilient Road Infrastructure Indicator Matrix is designed as a guiding framework and shall be adapted to suit the specific requirements and contextual conditions of each project.

14 Result Chain of Climate Resilient Road Infrastructure

The result chain of climate resilient road infrastructure explains how investments in resources and activities lead to improved road performance and long-term resilience. It begins with inputs such as funding, technical expertise, and climate data, which support the construction of resilient road features like

improved drainage, slope protection, and durable pavements (outputs). These lead to outcomes such as reduced road damage, better all-weather accessibility, and improved safety. Ultimately, the impact is a more climate-resilient road network, reduced economic losses, and enhanced connectivity and socio-economic development. The figure for result chain of climate resilient road infrastructure is given Figure 8.

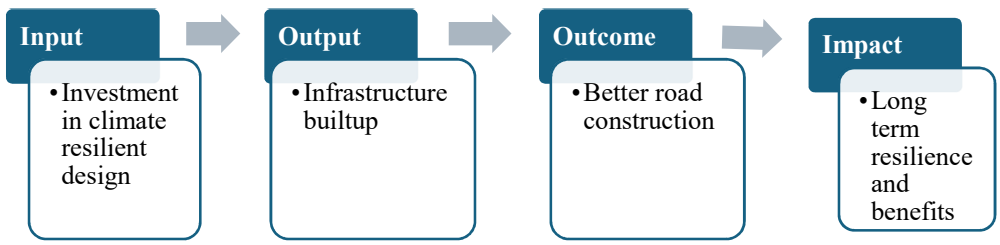


Figure 8: Result chain of climate resilient road infrastructure

Input
Resources used to implement climate-resilient road measures.

- Budget allocation for building resilience
- Climate data and studies (rainfall, flood, landslide)
- Climate resilient policy
- Construction materials (gabions, concrete, etc.)

Output
Immediate physical or technical results of the project.

- Roads constructed/upgraded with climate-resilient design
- Culverts, drainage systems, and toe walls installed
- Slope stabilization and bioengineering works completed

Outcome
Improved performance of roads due to these outputs.

- Reduced road damage during monsoon
- Improved drainage and fewer waterlogging issues
- Decreased landslides and erosion along road corridors

- All weather road accessibility

Impact
Long-term benefits and broader effects.

- Increased resilience of road networks to climate change
- Reduced maintenance costs and economic losses
- Improved safety and connectivity for communities
- Enhanced socio-economic development

ANNEXES

Annex 1: Draft Toolkit and Manual for Adoption by Road Engineers in Bagmati Province

Annex 1-A: Draft Toolkit for Application of NbS in Climate-Resilient Road Design, Construction and Maintenances in Bagmati Province.

Preamble: It is felt that a practical and easy-to-use toolkit and manual tailored for road infrastructure engineers in Bagmati Province, Nepal is needed especially to implement the Directives on Climate Resilient Infrastructure Design and Development. So this toolkit specifically focuses on the application of Nature-based Solutions (NbS) to build climate-resilient roads that are undoubtedly the most critical infrastructure in the province.

1. **Core Principles**
    - **Ecosystem-based design**: Integrate vegetation, soil, and water systems into road planning.
    - **Slope stabilization**: Use bio-engineering (grasses, shrubs, bamboo, vetiver) to reduce landslides.
    - **Hydrological balance**: Restore natural drainage, wetlands, and river buffers.
    - **Community co-benefits**: Align road safety with biodiversity, agriculture, and local livelihoods.
2. **Key NbS Techniques for Roads**

NbS Technique	Application in Roads	Benefits
Bio-engineering (vegetative slope protection)	bamboo, broom grass) on cut slopes	Reduces erosion, stabilizes slopes, low-cost
Check dams & gabions with vegetation	Combine stone gabions with live staking (willow, bamboo)	Controls gully erosion, dissipates water energy

NbS Technique	Application in Roads	Benefits
Green roadside drainage	Vegetated swales, infiltration trenches	Improves water percolation, reduces flooding
Riverbank stabilization	Riparian planting, brush layering	Protects roads near rivers, enhances biodiversity
Agroforestry buffers	Planting multipurpose trees along roads	Provides shade, fuel wood, reduces dust
Bio-retention ponds	Roadside water harvesting	Reduces peak runoff, supports irrigation, ground water recharge

3. **Design & Implementation Steps**
   i) Assessment
      - Conduct hazard mapping (landslides, floods, erosion zones).
      - Identify ecosystem services relevant to road alignment.

   ii) Planning
      - Integrate NbS into provincial road design standards.
      - Select species adapted to Bagmati's mid-hill and mountain ecology.

   iii) Construction
      - Train contractors in bio-engineering methods.
      - Use local materials and community labour for planting and maintenance.

   iv) Monitoring
      - Establish slope stability indicators (vegetation cover %, erosion depth).
      - Use digital dashboards for compliance reporting.

   v) Maintenance
      - Regular replanting, weeding, and water channel clearance.
      - Engage local communities for stewardship.

Annex 1-B: Draft Manual for Road Engineers on Application of Nature-Based Solutions (Nbs) for Climate-Resilient Roads, Bagmati Province, Nepal

Prepared For: Ministry of Physical Infrastructure Development (MOPID)

Preamble: The above described toolkit has been expanded into a formal provincial manual with annexes (species lists, slope stabilization diagrams, monitoring templates, compliance checklists). The structured manual template has different thematic sections, annexes, and sample tables ready for adoption by MOPID engineers in their work, especially in provincial road design, construction and maintenance. Once formalized by MOPID, Bagmati provincial manual can be applied directly by engineers and technicians. For easy understanding and adoption the manual has been structured like an official guideline document, with clear sections, annexes, and formatted tables/checklists for engineers and contractors. This manual is focused on engineers who can use it directly in design, contractors in construction, and provincial offices in compliance monitoring. The accompanying annex diagrams and sample monitoring tables in detail (ready-to-use field sheets) can be immediately piloted in Bagmati's road projects. The Manual has two parts as described below:

Part I: Outline

Section A: Policy & Standards

- Align with Bagmati Province Road Design Standards (Draft 2020).
- Integrate NbS into MoPID circulars and compliance checklists.

Section B: Technical Directives

- **Slope angle thresholds**: Apply bio-engineering for slopes >30°.
- **Species selection**: Vetiver for steep slopes, bamboo for riverbanks, broom grass for roadside stabilization.
- **Drainage design**: Incorporate vegetated swales instead of concrete-only channels.

Section C: Operational Tools

- **Field Manual**: Stepwise instructions for planting, staking, brush layering.
- **Monitoring Templates**: Tables for slope stability, vegetation survival rates, erosion depth.
- **Digital Workflow**: GIS-based participatory mapping of vulnerable road sections.

Section D: Case Studies

- **Narayanghat–Mugling Highway**: NbS slope protection reduced landslide risks.[4]
- **Rural Roads in Nepal (SWN)**: Bio-engineering Directives applied in foot trails and local roads.[3]

Part - II

Section 1: Introduction

- **Purpose**: Provide engineers with practical NbS methods for road design, construction, and maintenance.
- **Scope**: Provincial highways, rural roads, and feeder roads in Bagmati Province.
- **Principles**: Ecosystem-based design, hybrid engineering, community stewardship, climate resilience.

Section 2: Policy Alignment

- Aligns with:
    - Bagmati Province Road Design Standards (Draft 2020).
    - National Disaster Risk Reduction and Management Act (2017).
    - Nepal's National Adaptation Plan (NAP, 2021).
- MoPID Circulars: NbS must be integrated into compliance reporting and contractor Directives.

Section 3: Technical Directives

3.1 Slope Stabilization

- Apply bio-engineering for slopes >30°.

- Recommended species:
    - **Vetiver grass** (deep roots, steep slopes).
    - **Broom grass (Amriso)** for roadside stabilization.
    - **Bamboo** for riverbank reinforcement.
    - **Willow cuttings** for brush layering.

3.2 Drainage & Water Management

- Vegetated swales instead of concrete drains.
- Bio-retention ponds for runoff harvesting.
- Check dams with live staking in gullies.

3.3 Roadside Buffers

- Agroforestry belts with multipurpose trees.
- Riparian planting along rivers.

Section 4: Implementation Workflow

- **Assessment**: Hazard mapping (landslides, floods, erosion).
- **Planning**: Integrate NbS into design drawings and BoQs.
- **Construction**: Train contractors in bio-engineering methods.
- **Monitoring**: Use compliance dashboards and field templates.
- **Maintenance**: Community-based replanting and upkeep.

Section 5: Monitoring & Evaluation

Sample Monitoring Template

Indicator	Method	Frequency	Responsible
Vegetation survival rate (%)	Field survey	Quarterly	Contractor/ Community
Slope stability (erosion depth cm)	Visual + measurement	Biannual	Engineer
Drainage function	Flow check	Monsoon + post-monsoon	Road Division
Community engagement	Meeting records	Annual	MoPID

Section 6: Compliance Checklist

- [ ] Hazard mapping completed.
- [ ] NbS species selected per slope/zone.
- [ ] Bio-engineering integrated in BoQ.
- [ ] Contractor trained in NbS methods.
- [ ] Monitoring templates filled quarterly.
- [ ] Community stewardship plan in place.

Sub-Annexes

Sub-Annex A: Species List for NbS Application in Bagmati Province

- Vetiver grass (Chrysopogon zizanioides)
- Broom grass (Thysanolaena maxima)
- Bamboo (Dendrocalamus spp.)
- Willow (Salix spp.)
- Alder (Alnus nepalensis)

Sub-Annex B: Slope Stabilization Diagrams

- Brush layering cross-section.
- Live staking with gabions.
- Vetiver hedgerows on cut slopes.

Sub-Annex C: Monitoring Templates

- Vegetation survival table.
- Erosion depth log.
- Drainage function checklist.

Sub-Annex D: Compliance Reporting Format

- Digital dashboard fields (hazard zone, NbS applied, monitoring status).
- Contractor compliance sheet.

Risks & Challenges in NbS implementation

- **Species survival**: Poor maintenance leads to plant mortality.
- **Contractor resistance**: Preference for hard engineering solutions.

- **Institutional gaps**: NbS not yet mainstreamed in all provincial road standards.
- **Climate extremes**: Intense rainfall may overwhelm NbS if not combined with engineered structures.

Risk Mitigation or Management in NbS Application: Pair NbS with hybrid solutions (bio-gabions, vegetated retaining walls), ensure community-based maintenance, and embed NbS in MoPID compliance frameworks.

PART III: Sub-Annexes for Nbs Road Manual (Bagmati Province)

Sub-Annex 1-A: Species List (Field Reference)

Species	Local Name	Best Use	Notes
Chrysopogon zizanioides	Vetiver grass	Steep slope stabilization	Deep roots, drought-resistant
Thysanolaena maxima	Amriso (Broom grass)	Roadside slope cover	Provides broom income for locals
Dendrocalamus spp.	Bamboo	Riverbank reinforcement	Fast-growing, multipurpose
Salix spp.	Willow	Brush layering, live staking	Thrives in moist soils
Alnus nepalensis	Alder	Agroforestry buffer	Nitrogen-fixing, supports soil fertility

Sub-Annex 1-B: Slope Stabilization Diagrams (Field Sketches)

Diagram 1: Brush Layering

- Cut slope (30–45°)
- Horizontal trenches at 1 m intervals
- Willow cuttings laid along trenches, partially buried
- Soil compacted, vegetation cover established

Diagram 2: Vetiver Hedgerows

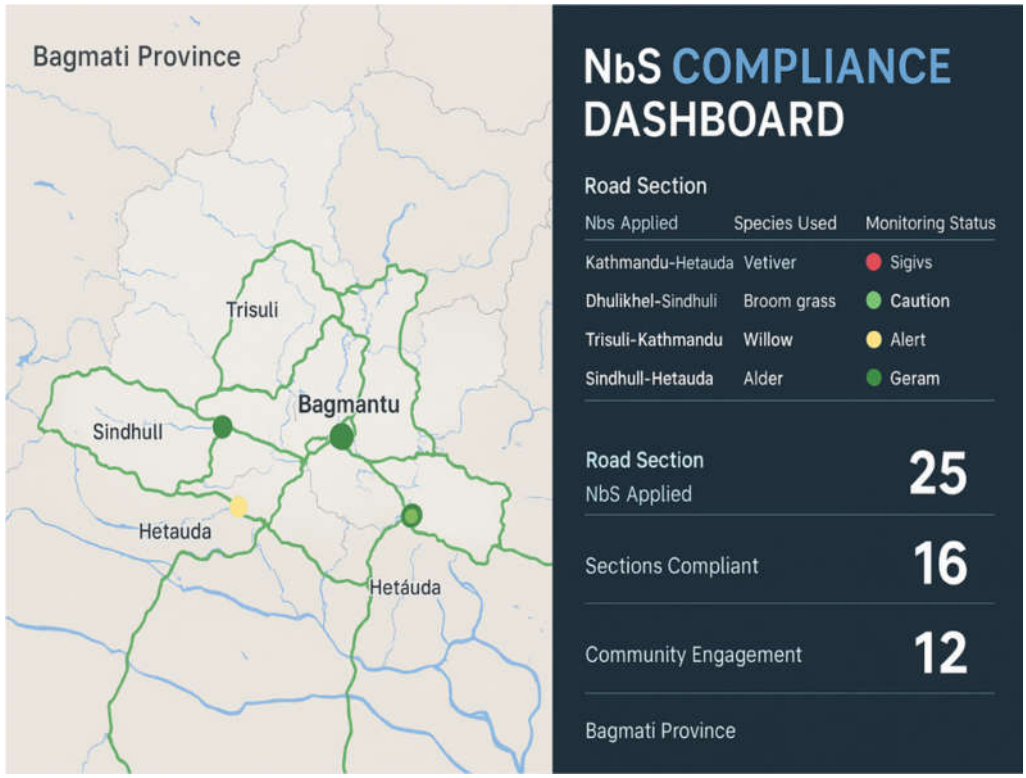
- Vetiver planted in contour lines across slope

- Spacing: 30–40 cm between plants
- Rows at 1 m vertical intervals
- Roots bind soil, hedgerows slow runoff

Diagram 3: Bio-Gabion Reinforcement

- Gabion wall at slope toe
- Live staking (bamboo/willow) inserted through gabion mesh
- Vegetation roots integrate with stone structure

Model dashboard layout: It is intended for MoPID to use as a prototype for monitoring NbS compliance across Bagmati Province's road network (digital link is also provided):



https://copilot.microsoft.com/th/id/BCO.d08dfad0-3382-48ba-a1cdf74189d1f388.png

Dashboard Features

1. GIS Mapping Layer

- Interactive map of Bagmati Province with **roads highlighted**.
- **Traffic-light indicators** (green, yellow, red) placed along road sections:
  - **Green** = compliant (NbS applied, monitoring satisfactory).
  - **Yellow** = caution (partial compliance, needs attention).
  - **Red** = critical (non-compliance, urgent intervention).
- Labels for major towns (Kathmandu, Dhulikhel, Sindhuli, Hetauda, Trisuli).
- Rivers and terrain features included for context.

2. Summary Table

Road Section	NbS Applied	Species Used	Monitoring Status
Kathmandu–Hetauda	Bio-engineering	Vetiver, Broom grass	Caution
Dhulikhel–Sindhuli	Drainage	Willow, Alder	Satisfactory
Trisuli–Kathmandu	Vegetated swales	Vetiver, Bamboo	Satisfactory
Sindhuli–Hetauda	Buffers	Bamboo, Alder	Critical

3. Performance Indicators

- **NbS Applied** → 25 sections
- **Sections Compliant** → 16 sections
- **Community Engagement** → 12 active stewardship groups

4. Sidebar Filters

- **District filter** (e.g., Kavre, Sindhuli, Makwanpur).
- **Road type filter** (highway, feeder, rural).
- **NbS type filter** (bio-engineering, drainage, buffers).

5. Monitoring Widgets

- Vegetation survival (%).
- Slope stability (erosion depth).
- Drainage function (swale/pond condition).

- Community engagement (meetings, stewardship plans).

Note: The above dashboard design allows MoPID to **visualize compliance in real time**, prioritize interventions, and track community involvement. It blends **GIS mapping** with **traffic-light indicators** and **performance metrics**, making NbS monitoring both technical and accessible. This will follow by a **step-by-step operational guide** for MoPID engineers to **populate and maintain the NbS Compliance Dashboard** for Bagmati Province. This guide ensures that the dashboard remains accurate, actionable, and responsive to field realities.

Operational Guide: NbS Compliance Dashboard for Bagmati Province

Step 1: Data Collection in the Field

Tools Needed:

- Printed monitoring templates (Annex C)
- GPS-enabled mobile device or tablet
- Species survival and erosion depth logs

Actions:

- Visit road sections and record:
    - NbS type applied (bio-engineering, drainage, buffers)
    - Species used (from Annex A)
    - Vegetation survival rate (%)
    - Erosion depth (cm)
    - Drainage functionality
- Capture geo-tagged photos and GPS coordinates

Step 2: Data Entry into Dashboard

Platform:

- MoPID's internal GIS dashboard (ArcGIS, QGIS, or custom)

Actions:

- Input road section ID and location
- Select NbS type from dropdown
- Enter species used (multiple selection)
- Upload field photos
- Fill monitoring indicators:
    - Vegetation survival rate
    - Erosion depth
    - Drainage status
- Assign traffic-light status:
    - Green = >80% vegetation survival, erosion <5 cm
    - Yellow = 50–80% survival, erosion 5–10 cm
    - Red = <50% survival, erosion >10 cm or drainage failure

Step 3: GIS Mapping & Visualization

Actions:

- Map each road section with:
    - NbS type symbol (e.g., leaf for bio-engineering)
    - Traffic-light indicator
- Overlay hazard zones (landslides, floods)
- Enable filters:
    - District (e.g., Kavre, Sindhuli)
    - Road type (highway, feeder)
    - NbS type (bio-engineering, drainage)

Step 4: Weekly Updates

Actions:

- Field engineers submit updated logs every Friday
- Dashboard manager reviews entries for accuracy
- Update traffic-light status based on new data
- Archive previous week's status for trend analysis

Step 5: Monthly Reporting

Outputs:

- Summary table of compliant vs. non-compliant sections
- Graphs: vegetation survival trends, erosion depth changes
- Community engagement log (meetings, stewardship plans)
- Export PDF report for MoPID leadership

Step 6: Community Feedback Loop

Actions:

- Share dashboard snapshots with local councils
- Invite feedback on maintenance and replanting
- Record community actions (e.g., replanting drives)

✅ **Roles & Responsibilities**

Role	Responsibility
Field Engineer	Data collection, template filling
Dashboard Manager	Data entry, GIS mapping, updates
MoPID Officer	Oversight, reporting, policy alignment
Local Council	Stewardship, feedback, maintenance

Printable field logbook template for MoPID engineers to carry during site visits. It aligns perfectly with the above described dashboard workflow and includes structured tables for vegetation survival, erosion depth, and drainage function.

Field Logbook for Road Engineers (Bagmati Province)

FIELD LOGBOOK
FOR ROAD ENGINEERS

Road Section _____
Date _____
Engineer _____

VEGETATION SURVIVAL LOG

Location	Species	Survival Rate (%)	Notes

EROSION DEPTH LOG

Location	Measurement (cm)	Date	Action Taken

DRAINAGE CHECKLIST

☐ Swales Clear	☐ Culverts Clear
☐ Bio-Retention Ponden	☐ Bio-Retention Pond Functioning
☐ Vegetation Cover >80%	

Header Section

- **Road Section Name**: _____
- **Date of Visit**: _____
- **Engineer's Name**: _____

1. Vegetation Survival Log

Location Species Survival Rate (%) Notes

2. Erosion Depth Log

Location	Measurement (cm)	Date	Action Taken

3. Drainage Checklist

- [ ] Swales Clear
- [ ] Culverts Clear
- [ ] Bio-Retention Pond Functioning
- [ ] Vegetation Cover > 80%

Note: This logbook ensures consistent field data collection, ready for dashboard entry and compliance tracking. It can be printed and distributed to all field engineers, with weekly submissions feeding into MoPID's digital system. It will be followed by a **companion digital entry form** (mobile/tablet-friendly) that mirrors this logbook for real-time dashboard updates from the field.

Companion Digital Entry Form: Field Logbook (Mobile Version)

Header Section

- **Road Section**: Text input
- **Date**: Calendar picker
- **Engineer Name**: Text input

1. Vegetation Survival Log

- **Location**: Text input
- **Species Used**: Dropdown (Vetiver, Broom grass, Bamboo, Willow, Alder)
- **Survival Rate (%)**: Slider (0–100%)

- **Notes**: Text box

2. Erosion Depth Log

- **Location**: Text input
- **Measurement (cm)**: Numeric input
- **Date**: Calendar picker
- **Action Taken**: Dropdown (Replanting, Brush layering, Gabion reinforcement, None)

3. Drainage Checklist

- [ ] Swales Clear
- [ ] Culverts Clear
- [ ] Bio-Retention Pond Functioning
- [ ] Vegetation Cover > 80%

Submit Button

- Large, touch-friendly **"Submit"** button
- Auto-syncs with dashboard backend
- Optional: GPS tagging and photo upload

Note: This form ensures **seamless field-to-dashboard integration**, enabling MoPID to maintain live compliance tracking across Bagmati's road network. It mirrors the printed logbook and supports both manual and digital workflows.

Annex C: Monitoring Templates

Vegetation Survival Log

Road Section	Species	Date Planted	Survival Rate (%)	Remarks
Example: Dhulikhel–Sindhuli	Vetiver	15 June 2026	85%	Needs replanting in upper slope

Erosion Depth Log

Road Section	Location	Measurement (cm)	Date	Action Taken
Example: Kavre Rural Road	Cut slope	12 cm	10-Aug-2026	Added brush layering

Drainage Function Checklist

- [ ] Swales clear of debris
- [ ] Bio-retention pond functional
- [ ] Check dams intact
- [ ] Vegetation cover >70%

Sub-Annex D: Compliance Reporting Format

Digital Dashboard Fields

- Road section ID
- NbS applied (bio-engineering, drainage, buffers)
- Species used
- Monitoring status (green/yellow/red)
- Community engagement record

Contractor Compliance Sheet

Requirement	Status	Verified By
Hazard mapping completed	☑	Engineer
NbS species selected	☑	MoPID
Bio-engineering integrated in BoQ	☐	Contractor
Monitoring templates filled	☐	Road Division
Community stewardship plan	☑	Local Council

With these annexes, the manual is now **operational**: engineers can carry field sheets, contractors can follow diagrams, and MoPID can track compliance digitally.

Annex 2: Directives to plan and conduct participatory infrastructure mapping\workshop

***Overview*:** Designing a participatory mapping session for resilient road building and using participatory mapping tools effectively means blending technical precision with community intuition. This section guide planners and engineers in Bagmati Province, especially for resilient infrastructure planning:

Step-by-Step Strategy for Effective Use

1. Pre-Workshop Preparation

- Define your goals: Are you mapping landslide-prone roads, health access gaps, or climate-vulnerable zones?
- Select the right tool:
- Kobo Toolbox for mobile surveys with GPS
- OpenStreetMap for editable community maps
- Maptionnaire for feedback-rich mapping dashboards
- Print base maps: Use satellite imagery or topographic maps for offline annotation.

2. During the Workshop

Community Engagement

- Start with a storytelling session: Let locals describe seasonal challenges, road failures, or health access issues.
- Use color-coded stickers or markers on printed maps:
  -  = hazard zones
  -  = safe routes
  -  = clinics/schools

Digital Mapping

- Equip teams with smartphones or tablets:
- Use KoBoToolbox to collect geotagged photos and road conditions.
- Let youth volunteers update OpenStreetMap with new paths or landmarks.

Feedback Loop

- Use Maptionnaire or Google Forms to gather opinions:
- “Which road segment needs urgent repair?”
- “What traditional methods help prevent erosion?”

3. Post-Workshop Integration

Data Consolidation

- Merge analog and digital inputs into a master map using QGIS or Google My Maps.
- Tag community insights (e.g., “This slope floods every Dashain”) for planners.

Dashboard Creation

- Build a resilience dashboard:
- Show mapped hazards, priority zones, and community suggestions.
- Link it to your resilient road toolkit for MoPID engineers.

Bonus Tips for Sustainability

- Train local youth or ward officials as mapping ambassadors.
- Schedule seasonal updates — monsoon vs. dry season conditions.
- Use maps in public hearings or budget planning to advocate for community needs.

A sample Participatory Mapping Sheet & Dashboard Layout for Bagmati Province has been designed for both print and digital use in MoPID workshops and community engagement sessions. It includes the following elements:

Participatory Mapping Sheet (Page 1)

- Base Map Area: Large annotation space for marking hazard zones, blocked roads, clinics, and schools.
- Color-Coded Legend:
    - Hazards
    - Safe Routes
    - Clinics
    - Schools
        - Icons:
    - Landslide

    - Erosion
    - Blocked Road
    - Health Post
- QR Code: Links to a digital dashboard and feedback form for community input.

Digital Dashboard Layout (Page 2)

- Mapped Community Inputs: Visual overlays of hazard zones and priority roads.
- KoBoToolbox & OpenStreetMap Integration: Field data and community edits.
- Feedback Summary: Insights from Maptionnaire or Google Forms.
- Toolkit Integration: Matches the visual style and color scheme of your Resilient Road Toolkit.

This layout is perfect for:

- Field validation with engineers and locals
- Training sessions and youth engagement
- MoPID planning and policy briefings

Annex 3: Guiding Principles of Route Selection and Alignment Improvement

A. General

- The road should be as direct as possible between the cities or towns to be linked, thereby, satisfying the major desired links. A direct highway link results in the economy in construction, maintenance, and operation.
- The location should result in minimum interference to agriculture and industry.
- The location should, as far as possible, facilitate easy grades and curvature.
- The location should steer clear of obstruction, such as cemeteries, burning Ghats, places of worship, archaeological and historical monuments, and as far as possible, from public facilities, like hospitals, schools, playgrounds, etc.
- Where the proposed location interferes with utility services, like overhead transmission lines. Water supply lines, etc., a decision between changing the highway alignment or shifting the utility services should be based on the study of relative economics and feasibility.
- An important obligatory point in the selection of the route is the location of river crossings. While crossings of major rivers (waterway exceeding 200 m.) may have to be as normal to the river flow if possible, with highway alignment sub-ordinated to considerations of the bridge sitting. Crossings of medium/minor streams should be generally governed by the requirements of the highway proper. If necessary, such structures could be made skew/located on curves.
- The location should be such that the road is fully integrated with the surrounding landscape of the area. In this connection, it would be necessary to study the environmental impact of the highway and ensure that the adverse effects of it are kept to a minimum.
- The highway should, as far as possible, be located along edges of properties rather than through their middle to cause the least interference to cultivation and other activities and to avoid the need for the frequent crossing of the highway by the local people.

- The location should be, such as, to avoid unnecessary and expensive destruction of wooded areas. Where intrusion into such areas is unavoidable.
- The road should be aligned on a curve, if possible, to preserve an unbroken background.
- The location should, as far as possible, be close to sources of embankment axil pavement materials so that haulage of these over long distances is avoided and the cost minimized.
- A preferred location is one which passes through areas having the better type of soil and permits a balancing of the cost of the cut and fills for the formation.
- Marshy and low-lying land and areas having poor drainage and very poor embankment material should be avoided, as far as possible. Also, areas susceptible to subsidence due to mining operations should be by-passed.
- Areas liable to flooding should be avoided, as far as possible.
- Highways through villages and towns increase traffic hazards and cause delays and congestion. Wherever a serious problem of this nature is encountered it may be advisable to bypass the built-up area playing well clear of the limits up to which the town or village is anticipated to grow in the future.
- As far as possible, areas likely to be unstable due to toe-erosion by rivers shall be avoided.

B. Special Problems of Locating in Hilly Areas

- The route should enable the ruling gradient to be attained in most of the length.
- Steep terrain and other inaccessible areas should be avoided, as far as possible.
- Unstable hilly features, areas having frequent landslide or settlement problems, and upslope benched agricultural field with potential for standing water may be avoided as far as possible.
- Locations, along a river valley, have the inherent advantage of comparatively gentle gradients, proximity of inhabited villages, and

easy supply of water for construction purposes. However, this solution is be-set with disadvantages, such as the need for a large number of cross-drainage structures and protective works against erosion. It would, therefore, be necessary to take the various aspects into account before making the final selection.

- The alignment should involve the least number of hairpin bends. Where unavoidable, the bends should be located on stable and gentle hill slopes.
- In certain cases, it may be expedient to negotiate high mountain ranges through tunnels. For such cases, the decision should be based on relative economics or strategic considerations.
- In crossing mountain ridges, the location should be such that the highway preferably crosses the ridge at their lowest elevation.
- An alignment likely to receive plenty of sunlight should receive due to preference over the one which will be in shade.
- Areas liable to snowdrift should be avoided.
- As far as possible, needless rise and fall must be avoided, especially where the general purpose of the route is to gain elevation from a lower point to a higher point.
- Areas of valuable natural resources and wildlife sanctuaries shall be avoided.

Annex 4: Design Parameters for Resilient Provincial Roads

Table: Design Parameters for Provincial Roads

Design parameter	**Province Roads**			
	I	**II**	**III**	**IV**
Design Capacity, PCU day	>10000	5000-10000	1000-5000	<1000
Design Speed, mph	P-120 R-100 M-80 S-60	P-100 R-80 M-60 S-40	P-80 R-60 M-40 S-30	P-60 R-40 M-30 S-20
No. of Lanes	4 min	>=2	2	1
Lane Width, m	3.75	3.5	3.5	5.5
Shoulder Width (minimum), m	P,R-3.75 M,S-2.5	P,R-2.5 M,S-2.0	P,R-2.0 M,S-1.0	P,R-1.5 M-0.75 S-0.50
Median Strip, m	3.50	-	-	-
Minimum Radius of Hor. Curve (when super elevation is not provided), m	P-800 R-500 M-300 S-200	P-400 R-250 M-150 S-60	P-250 R-150 M-60 S-30	P-150 R-60 M-30 S-15
Minimum K- Value for Vertical Curves (Summit/Valley)	P-807/441 R-427/236 M-231/111 S-94/42	P-427/236 R-231/111 M-94/42 S-29/17	P-231/111 R-94/42 M-29/17 S-4/6	P-94/42 R-29/17 M-4/6 S-2/3
Minimum Gradient	0.5	0.5	0.5	0.5
Maximum Longitudinal Gradient, %	P-4	P-5	P-6	P-7
	R-6	R-6	R-7	R-9
	M-6	M-7	M-9	M-10
	S-7	S-9	S-10	S-12
RoW in both side from CL	21	15	12	10
Maximum Super Elevation	P,R- 7%, SB-7%, Hill not bound by snow-10%			
Critical Length of Maximum Gradient	P-600	P-450	P-400	P-300
	R-450	R-400	R-300	R-200
	M-400	M-300	M-200	M-150

Design parameter	Province Roads			
	I	II	III	IV
	S-300	S-200	S-150	S-150
Cross Slope	As per Pavement Type			

(Source: Bagmati Provincial Road Standard, 2076)

Loss & Damage table **Palika: ……** **District: ……**

Wards	Types of disasters	Human							
		Casualties		Injured		Land loss	Agri. Production losses	Livestock	others
		Male	Female	Male	Female				
	Landslides								
	Floods								
	GLOF								
	Earthquake								
	….....								
	….....								
	….....								
	….....								
	….....								
	….....								
	Total								

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**********END**********

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