ADDRESSING INFRASTRUCTURE AND CONNECTIVITY CHALLENGES TO UNLOCK KARNALI PROVINCE'S ECONOMIC POTENTIAL: A PATHWAY TO SUSTAINABLE RURAL DEVELOPMENT

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ABSTRACT

Karnali Province, in north-western Nepal, remains among the most infrastructure-constrained regions in the country despite its wealth of natural, cultural, and hydro-power potential. As of 2025, the province continues to struggle with limited road connectivity, unreliable power, digital divides, and weak social services. In this article, I reassess its development status using the latest government and donor data, focusing on transportation, energy, digital infrastructure, and social services. I examine flagship efforts like the Karnali Corridor, rural electrification schemes, and the "Digital Karnali" initiative, and assess their roles in catalysing economic transformation. I argue that coordinated, climate-resilient, and inclusive infrastructure investments, paired with strong institutions, innovative financing, and community participation, can unlock pathways to agricultural commercialization, tourism growth, renewable energy development, and rural poverty reduction. The article closes with policy recommendations and a holistic framework for sustainable rural development in Karnali and other mountainous provinces.

Keywords: Karnali Province, infrastructure, connectivity, rural development, sustainable growth, corridor development, inclusion

1. INTRODUCTION

Karnali Province is arguably Nepal's most challenging development environment. As of the latest available data, the province covers 27,984 square kilometers and hosts roughly 1.75 million people across its ten districts (Central Bureau of Statistics [CBS], 2023). It is the largest province by area but the least populous. Its terrain ranges from subtropical lowland basins to high Himalayan peaks, affording enormous ecological diversity but also posing high costs for connectivity and service delivery.

Despite its land area and resource base, the province lags behind in socio-economic indicators. According to the National Planning Commission (NPC, 2024), around 38 percent of the Karnali population lives below the national poverty line, a modest improvement from over 45 percent in 2020, but still the highest rate in Nepal. Although Karnali makes up approximately one-fifth of the country's land, its contribution to national GDP remains under 6 percent. Over 75 percent of its households depend on smallholder, subsistence agriculture, and migration is a key livelihood strategy; remittances account for nearly 30 percent of household incomes in many areas (Ministry of Finance [MoF], 2025).

At the core of these structural constraints lies a pronounced infrastructure deficit. The Department of Roads (DoR, 2024) reports that only about 35 percent of Karnali's Road network is paved, while road density is a mere 0.17 km per square kilometer, far below Nepal's national average of 0.38 km/km². Electricity has reached roughly 78 percent of households, though

supply quality is poor (Nepal Electricity Authority [NEA], 2025). Internet penetration stood at about 42 percent by mid-2025, with sharp disparity between urbanized pockets like Birendranagar and frontier districts such as Humla and Dolpa (Nepal Telecommunications Authority [NTA], 2025).

This paper explores how closing infrastructure bottlenecks can turn Karnali's latent potentials into sustainable rural development. After reviewing the infrastructure landscape and highlighting ongoing flagship initiatives, it discusses sectoral opportunities, institutional challenges, and financing options. The analysis leads to a proposed integrated, resilient development framework aimed at accelerating inclusive growth in Karnali, and offers lessons applicable to other mountainous, marginalized regions.

2. Infrastructure Gaps and Their Impacts

2.1 Road and Transport Connectivity

Transportation remains perhaps the most binding bottleneck. As of 2025, Karnali's road network has expanded to about 4,850 kilometers from around 4,200 km in 2021 (DoR, 2024), yet only about 420 km (8.6 percent) are blacktopped (DoR, 2024). Many roads in mountainous districts are seasonal or frequently disrupted by landslides, flooding, or damaged culverts. For example, routes to Dolpa and Mugu become impassable for weeks during monsoon seasons, severely disrupting supply chains and hindering access to essential services.

Because of these obstacles, transportation costs in Karnali are estimated to be up to 300 percent higher than in the Terai or other lowland regions (Asian Development Bank [ADB], 2024). These costs not only raise consumer prices but reduce the price farmers receive at the farm gate, dampening incentives to produce high-value or perishable crops.

The consequences of low connectivity reach beyond economic loss. In health, the Nepal Health Research Council (NHRC, 2023) notes that in remote districts, over 40 percent of pregnant women must travel more than three hours to reach a birthing centre, compared to a national average travel time of about one hour. In education, secondary school enrolment rates in high-mountain zones are 22 percent lower than national averages (Ministry of Education, Science, and Technology [MoEST], 2024), largely due to distance, lack of reliable roads, and seasonal closures.

2.2 Energy Access and Power Reliability

Karnali sits atop vast hydropower potential, estimates suggest over 12,000 MW. Yet the province's installed capacity remains below 80 MW (NEA, 2025). The 132 kV transmission extension from Surkhet to Dailekh and Jumla (completed in 2024) improved connectivity for some districts, but voltage fluctuations and frequent outages remain common (NEA, 2025).

About 22 percent of households still rely on traditional biomass fuels for cooking, which disproportionately affects women through indoor air pollution and the labour cost of gathering fuelwood (Alternative Energy Promotion Centre [AEPC], 2024). Off-grid renewable systems, micro-hydropower and solar mini-grids, have proliferated: over 300 micro-hydro projects and 1,200 institutional solar systems are in operation (AEPC, 2024). However, 28 percent of these systems face technical or maintenance problems, reflecting weak local capacity and limited aftercare mechanisms.

An ambitious project, the Upper Karnali Hydropower Project (900 MW), is in advanced planning. It is designed as a run-of-river plant largely intended for export (with Nepal retaining around 108 MW for domestic use) (Wikipedia, 2025). If realized, it could transform the energy landscape, but strong institutional, environmental, and financial arrangements are essential.

2.3 Digital Infrastructure and Inclusion

Digital connectivity in Karnali has progressed, especially since the launch of the Digital Karnali Program in 2023. As of 2025, 4G coverage reaches about 86 percent of the population, and 5G trials are under way in Surkhet and Jumla (NTA, 2025). The 2025 Digital Karnali Conclave report describes this initiative as a "collective drive" to bring government services, business, education, and health onto digital platforms (Digital Karnali Conclave, 2025).

Yet challenges remain. Digital literacy is low, especially among older people and those with minimal formal schooling. Only about 37 percent of households report using digital financial services, compared with 72 percent in Bagmati Province (Nepal Rastra Bank [NRB], 2025). Many remote hamlets still lack reliable mobile or fiber connectivity, limiting opportunities for e-commerce, telemedicine, distance education, or digital governance.

2.4 Social Infrastructure: Health, Education, Water

Social services in Karnali also suffer from infrastructure deficits. The province's doctor-to-population ratio is about 1:13,000 (Ministry of Health and Population [MoHP], 2024), much worse than the national average of 1:4,500. Numerous health facilities lack adequate buildings, equipment, medicines, or even reliable electricity.

In education, approximately 35 percent of schools lack permanent infrastructure, and nearly half lack functional toilets, posing disproportionately large barriers for girls (MoEST, 2024). Water supply coverage has reached 82 percent, but only 45 percent of households have piped water inside their premises, and many municipalities (e.g. Surkhet, Dailekh) suffer seasonal shortages (Department of Water Supply and Sewerage Management [DWSSM], 2024).

These deficits combine to perpetuate human development disadvantage. Poor health outcomes lead to high morbidity and mortality. Unsafe water and sanitation amplify disease burdens. Weak educational infrastructure constrains learning outcomes and workforce skills. Thus, infrastructure investment is not just economic, but intrinsically human development.

3. Flagship Initiatives and Infrastructure Momentum

In recent years, the provincial and federal governments, with support from development partners, have initiated a series of projects aimed at breaking the isolation trap. Below I review key initiatives and their challenges as of 2025.

3.1 Karnali Corridor

The Karnali Corridor is the province's infrastructural flagship. Conceptualized as a roughly 1,100-kilometer network, it aims to connect all district headquarters to the Mid-Hill Highway and the national grid. The vision goes beyond roads, it integrates power lines, fiber optics, and market infrastructure into a multi-modal development corridor.

As of mid-2025, about 58 percent of the corridor, particularly the Surkhet–Jumla and Jajarkot–Dolpa segments, is either completed or under advanced construction (DoR, 2025). The corridor aligns with the Karnali Highway (NH-58), which links Jamunaha (Banke) to Hilsa (Humla), spanning around 505 km (Wikipedia, 2025). A notable milestone was the inauguration of a Bailey bridge over the Chuwakhola River in July 2025, which connected Humla'sSimkot to the national road network, ending decades of isolation (Himal Press, 2025; Farsight Nepal, 2025).

Political leadership has pushed the corridor's ambitions further: Prime Minister KP Sharma Oli has repeatedly pledged to promote the corridor as a trade route linking Nepal with China and India (Nepal Page, 2025; Himalayan Times, 2025). The Nepal Competitiveness Index (2025) highlights, however, that Karnali still lags in "Governmental and Institutional Settings," suggesting that the corridor's promise hinges on institutional reforms (LKY School, 2025).

The NPC (2024) estimates that once the corridor is fully functional, it could boost the province's GDP growth by as much as 2.8 percentage points annually. It would lower transport costs, stimulate private investment, and integrate local markets more tightly. The corridor's design intentionally couple's road, power, and broadband investments, a lesson borrowed from Southeast Asia's integrated development corridors (ADB, 2023).

Complementary initiatives support the corridor's resilience. The Karnali Resilient Infrastructure Project (2023–2028), co-funded by the World Bank, emphasizes slope stabilization and climate-proofing of bridges. The Provincial Road Maintenance Program introduces performance-based contracts to maintain road quality over time. At the same time, the Karnali Energy Access Project (launched in 2024 with ADB assistance) commits to electrifying 120,000 rural households via grid extension and off-grid systems.

Yet major challenges persist. Because of steep topography and fragile geology, average blacktopping costs in upper Karnali may reach NPR 45 million per kilometer, nearly twice the national average (DoR, 2025). Funding gaps are large: the fully realized corridor may cost more than USD 2.4 billion. Ensuring that marginalized and indigenous communities benefit equitably, rather than being by passed, is a constant policy challenge (National Human Rights Commission, 2024).

3.2 Rural Roads and Local Connectivity

Beyond the main corridor, the Karnali provincial government has launched a program to build 1,000 rural roads, budgeting about NPR 8 billion (Nepal News, 2025). However, shortages in skilled human resources and project management capacity slow implementation.

Progress reports note scattered advances: for example, 2.5 km of new road opened in Ghatparichaur–Badrigaun–Bhukkakhola and 11 km in LaliBagar–sections (Clickmandu, 2025). Other rural segments, such as Bhulbhulaiya–Mugu, have been carved across rugged hills to improve access and integrate remote districts (Rising Nepal, 2025). Yet many localities still rely on precarious suspension bridges ("tuins") that pose danger especially in the monsoon (Kathmandu Post, 2025).

Programs such as the Local Infrastructure Support Programme (LISP) are piloting local road improvement models in Karnali, aiming to scale up community-led, small-scale infrastructure (Frontier Studies, 2025).

3.3 Digital Karnali and ICT Infrastructure

Launched in 2023, the Digital Karnali Program is central to bridging the province's digital divide. The 2025 Digital Karnali Conclave report describes how provincial, federal, and private actors are pooling efforts to extend broadband, improve local e-services, and expand digital literacy (Digital Karnali Conclave, 2025). As noted earlier, 4G now reaches 86 percent of the population; 5G experimentation is underway in Surkhet and Jumla (NTA, 2025).

The plan envisages fiber-optic backbone lines running parallel to the corridor, enabling broadband "last-mile" access to schools, health posts, and community hubs. However, gaps in fiber, last-mile connectivity, and local digital skills remain hurdles.

3.4 Renewable Energy and Off-Grid Systems

Complementing grid expansion is a focus on decentralized renewables. Over 300 micro-hydro systems and 1,200 solar institutional installations are functioning (AEPC, 2024). But around 28 percent report faults or require maintenance, highlighting weak local technical capacity.

The Karnali Energy Access Project (2024) targets grid/off-grid hybridization for 120,000 rural homes. Combined with micro-grid expansion, solar-hybrid systems, and mini hydropower, the energy strategy envisions incremental expansion beyond the grid's economic reach.

Large-scale hydropower projects remain aspirational. In addition to the Upper Karnali project, schemes such as Nalgad (410 MW) and Jagdulla (190 MW) are in environmental assessment phases. If implemented, these could substantially raise Karnali's share in national energy supply (NEA, 2025).

3.5 Social Infrastructure and Institutional Support

While physical connectivity induces economic possibilities, social infrastructure must keep pace. The provincial government has prioritized construction or upgrading of health centres, schools, water supply systems, and sanitation infrastructure. Simultaneously, capacity-building at provincial and local levels is underway, though institutional constraints remain acute.

Karnali's Infrastructure Master Plan (2024–2034) attempts to integrate sectoral investments, roads, power, digital, and social infrastructure, into a spatially coherent, inclusive plan. The blueprint emphasizes green growth, eco-tourism, organic farming, digital inclusion, and community-led development (Karnali Provincial Planning Commission [KPPC], 2025).

4. Sectoral Opportunities Unlocked by Better Infrastructure

Effective infrastructure is foundational. But real transformation emerges when sectors pivot from subsistence toward commercial viability. Here we examine how improved connectivity can unlock high-impact sectors in Karnali.

4.1 Commercial Agriculture and Value Chains

Agriculture remains the backbone of Karnali's rural economy. With improved roads and power, farmers are beginning the shift toward semi-commercial, value-added production.

In districts like Surkhet, Dailekh, and Salyan, farmers now grow off-season vegetables, apples, and walnuts destined for markets in Nepalgunj and Kathmandu. Cold storage units in Surkhet

and Jumla, enabled by more reliable electricity, have helped reduce post-harvest losses. According to the Ministry of Agriculture and Livestock Development (MoALD, 2024), commercial vegetable output in Karnali rose by 35 percent from 2021 to 2024.

Medicinal and aromatic plants, such as Yarsagumba and Jatamansi, offer high-margin seasonal income. But unregulated harvesting has led to ecological degradation and unfair market terms. The Department of Forests and Environment (2024) has rolled out certification-based trade systems to encourage sustainable harvesting and fair trade.

Non-timber forest products (NTFPs) provide yet another avenue. In Jumla, Kalikot, and Dailekh, small enterprises process herbs, essential oils, and bamboo crafts. Value addition is still nascent, but cooperative-led models, improved roads, and better market access are facilitating growth (Pyakurel, Bhattarai, & Sharma, 2024).

The potential ripple effects are large: improved infrastructure reduces transport costs, increases market choices, and allows aggregation and scale. Farmers gain better prices, local processors gain access to supplies and markets, and rural incomes diversify away from remittances.

4.2 Mountain and Adventure Tourism

Karnali's rugged landscapes, alpine lakes, and remote culture are ideal for high-end eco-tourism and adventure trekking. Visitor numbers to destinations like Rara National Park and Shey Phoksundo have grown from 25,000 (pre-pandemic) to over 70,000 in 2024 (Ministry of Culture, Tourism and Civil Aviation [MoCTCA], 2025). Upgraded airstrips in Rara, Dolpa, and Simkot, plus improved road access, have helped this growth (Nepal Tourism Board [NTB], 2025).

Moreover, in 2025, the Government of Nepal waived mountaineering fees for 97 peaks in the remote Himalayas, many of which lie in Karnali and Sudurpashchim provinces to stimulate tourism in these underexplored areas (Reuters, 2025). This move is expected to attract climbers to new routes and expand high-value tourism in remote zones.

Community-based tourism, such as homestays and local guiding is expanding, especially in Mugu and Dolpa. The NTB reports that these schemes now provide over 1,500 jobs, with earnings staying in local communities (NTB, 2025). But to scale further, consistent access roads, reliable electricity, wireless connectivity, waste management, and trained hospitality services are essential.

4.3 Renewable Energy and Local Industry

Once fully operational, large hydropower and distributed renewables can power not only households but local industries. For example:

a) Cold storage, dairy chilling centers, and agro-processing units require steady electric supply.
b) Solar-grid hybrid systems can power mills, small factories, and ICT hubs in distant valleys.
c) Access to surplus electricity may attract small manufacturing or remote service firms.
d) For instance, the 900 MW Upper Karnali project with export orientation, could also enable local industry if regulatory arrangements prioritize local allocation (Wikipedia, 2025). Smaller projects like Nalgad and Jagdulla offer more locally distributed

opportunities. In total, NEA (2025) has identified more than 5,000 MW of hydropower potential in the province.

4.4 Logistics, Trade, and Cross-Border Potential

The Karnali Corridor design explicitly envisions cross-border trade. As the PM has pledged, the corridor may position Karnali as a trade conduit linking Nepal, India, and China (Nepal Page, 2025; Himalayan Times, 2025). Upon completion, Simkot (Humla) will integrate into trans-Himalayan trade routes, potentially opening new export and import channels.

Upgraded logistics facilities, cold chains, and warehouses along the corridor could further stimulate industrial corridors, agro-logistics hubs, and value chain industries, turning Karnali from a periphery into a zone of transit trade and economic density.

5. Governance, Financing, and Policy Coordination

Better infrastructure alone is insufficient. Institutional quality, governance, financing mechanisms, and inclusion must accompany physical investments. Below are key enablers and challenges.

5.1 Multilevel Coordination and Institutional Capacity

Nepal's federal structure assigns significant responsibilities for infrastructure to federal, provincial, and local governments. Coordination failures can lead to duplication, misaligned priorities, or gaps. In Karnali, the Karnali Provincial Planning Commission (KPPC, 2025) has begun integrated spatial planning to align road, power, digital, and social investments. This planning is a crucial step toward coherence.

Yet gaps in technical design, procurement capabilities, project monitoring, and maintenance capacity remain large. Many local municipalities lack qualified engineers or systems for contracting and oversight. The Nepal Competitiveness Index (2025) flags Karnali's performance in institutional settings as weak (LKY School, 2025). Capacity building, especially in local governments, is a critical frontier.

5.2 Budget Absorption and Execution Efficiency

A recurring challenge is low capital budget absorption. Over the past three years, Karnali's capital expenditure absorption averaged only 72 percent of allocated funds, indicative of delays in project preparation, procurement, and execution (MoF, 2025). Underutilized budgets represent lost development opportunities and increased unit costs.

Donor agencies such as ADB (2024) and the World Bank (2025) stress the importance of project readiness, streamlined procurement, and performance-based budgeting to improve yield from infrastructure investments.

5.3 Financing Large Infrastructure

The ultimate cost of bringing the Karnali Corridor, energy networks, and digital infrastructure to full scale exceeds the fiscal capacity of provincial budgets or even federal grants. Donor financing is indispensable, but it cannot substitute for sustainable domestic resource mobilization.

Public-private partnerships (PPPs) are slowly gaining traction. The Investment Board Nepal (IBN, 2025) is encouraging PPP models in small hydropower, cable-car tourism, and agri-logistics infrastructure. But the private sector remains cautious given risks of low returns, regulatory uncertainty, and weak institutional guarantees.

Innovative financing models, such as blended finance (mixing public, private, and donor sources), community bonds, or ecosystem service payments (e.g., carbon credits), could help fill gaps. Access to concessional climate funds (e.g., Green Climate Fund) may support resilient infrastructure. Clear policies, transparent governance, and risk-sharing mechanisms are essential to attract private capital.

5.4 Inclusion, Gender, and Social Safeguards

Ensuring equitable benefits is not optional. Infrastructure projects must reach marginalized populations, including women, indigenous groups, and remote hamlets. The National Human Rights Commission (2024) emphasizes integrating social inclusion safeguards into project design and monitoring.

Gender-responsive planning, in road siting, labor opportunities, service access, is vital. Women's involvement in planning and monitoring can help align infrastructure with community needs (e.g., placement of health posts, water points, market access). Community-based oversight committees can promote accountability and local ownership.

6. Toward an Integrated, Sustainable Development Framework

To make infrastructure truly transformative, its design and deployment must be embedded within a broader systems framework. Below is a proposed pathway.

6.1 Spatially Integrated Infrastructure Planning

Rather than treating roads, power, digital lines, social services, and water systems as separate silos, investments should follow spatial integration. The corridor must serve as a backbone, roads aligned with fiber and power lines, connecting growth hubs, local markets, and social facilities.

Integrated spatial planning (by KPPC) can map production zones, service clusters, population centers, and environmental constraints to optimize infrastructure layout. This avoids redundant investments, reduces cost, and amplifies synergies.

6.2 Mainstreaming Climate Resilience and Environmental Safeguards

Mountainous roads, power lines, and dams are vulnerable to landslides, erosion, and extreme weather. All infrastructure designs must incorporate drainage, slope stabilization, bioengineering, and ecosystem restoration measures.

Green infrastructure (e.g., planted buffer zones), early warning systems, and climate-responsive maintenance regimes should be standard. Projects must adhere to environmental impact assessment standards and avoid fragile ecological zones.

6.3 Institutional Strengthening and Decentralized Capacity

Infrastructure success hinges on local capacity. A systematic program to build technical, managerial, procurement, and monitoring skills in provincial and municipal staffs is critical. Partnerships with universities, NGOs, and the private sector can sustain capacity growth.

Standardized procedures, digital project management systems, transparent bidding, and performance-based contracting help reduce delays, cost overruns, and corruption risks.

6.4 Financing Innovation and Sustainability

To mobilize resources:

a) Blend public, donor, and private financing.

b) Use performance-based contracts and maintainable design standards.

c) Tap climate and development funds.

d) Employ community financing models, such as bonds or local co-financing, for smaller roads or electrification.

e) Use differential pricing or cross-subsidy mechanisms for energy and digital services in remote areas.

A multi-year financing roadmap must match the phasing of corridor segments, energy projects, and social infrastructure.

6.5 Digital Inclusion and Human Capacity

Infrastructure alone is inert unless people can use it. Digital literacy programs, especially at schools, community centers, and through NGOs, are essential to expand e-services, telemedicine, distance learning, e-commerce, and digital governance.

Entrepreneurship training, business incubation, and local enterprise development should be integrated with infrastructure rollout. Women, youth, and marginalized groups must be prioritized in training, access to credit, and inclusion schemes.

6.6 Participatory Planning and Social Accountability

Local communities must be active partners, not passive beneficiaries. Participatory planning, social audits, and feedback mechanisms help align infrastructure with local priorities and promote transparency. Oversight committees, and gender- or minority-inclusive representation, can help ensure equitable outcomes.

6.7 Monitoring, Evaluation, and Adaptive Learning

Robust monitoring and evaluation systems are key. Baselines, milestone indicators, and impact evaluation protocols should be built into projects from the start. Learning loops should allow mid-course corrections, scaling of successful pilots, and avoidance of repeating mistakes.

7. Conclusion and Policy Recommendations

Karnali Province stands at a crossroads. Its isolation has long constrained its development, but the current momentum, roads under construction, power lines extending, digital initiatives scaling, signals the possibility of transformation. However, infrastructure by itself is not enough. Without strong institutions, inclusive policies, sustainable financing, and community empowerment, these projects risk becoming white elephants or reinforcing inequalities.

To realize Karnali's full potential, the following policy agenda is urgent:

a) Accelerate and complete the Karnali Corridor with integrated power and digital systems, error-proof design, and linkage to trans-Himalayan trade routes.

b) Strengthen local capacities in municipalities and provincial agencies across design, procurement, maintenance, and project management.

c) Innovate financing models via PPPs, blended finance, community bonds, and climate funds.

d) Embed social inclusion and gender equity in all stages: design, implementation, oversight, and benefit-sharing.

e) Mainstream climate resilience and environmental safeguards in every infrastructure project.

f) Prioritize digital inclusion and human capacity building to ensure technology and infrastructure deliver real benefits.

g) Establish rigorous M&E and adaptive systems to track progress, learn, and adjust.

h) Promote institutional coordination across federal, provincial, and local levels to avoid duplications, gaps, or overlap.

If implemented faithfully, the Infrastructure Master Plan (2024–2034) could, by some projections, halve multidimensional poverty in Karnali within a decade (NPC, 2024). More than economic development, this is a question of dignity, equity, and justice: roads connect farmers to markets, electricity powers education and enterprise, and digital links bring isolated people into the national conversation.

Karnali's journey is not just its own; it offers lessons for mountainous, marginalized regions worldwide. With steady commitment across levels of government, meaningful community engagement, and smart financing, Karnali has the potential to evolve from Nepal's most remote province into a model of sustainable, inclusion-driven rural transformation.

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