

SYSTEMIC BARRIERS TO SUSTAINABLE RURAL ROAD INFRASTRUCTURE: A GLOBAL REVIEW AND STRATEGIC FRAMEWORK**Olimjonova Sevinchoy Muzaffarbek qizi**

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<https://doi.org/10.5281/zenodo.20187970>**ABSTRACT**

Sustainable rural road infrastructure is a decisive precondition for inclusive growth, food security, access to education and health care, regional integration, and the spatial reduction of poverty. Yet many countries continue to face a persistent gap between road construction and road sustainability. New rural roads are often financed as visible capital projects, while maintenance, climate adaptation, community accountability, technical quality control, and long-term asset management receive weaker institutional attention. This article presents a global review of systemic barriers that limit the sustainability of rural road infrastructure and proposes a strategic framework for policy, financing, engineering, governance, and social inclusion. The analysis draws on international evidence from the World Bank, Sustainable Mobility for All, the Asian Development Bank, ILO-oriented labor-based rural road approaches, European road asset management practices, CIS and Central Asian institutional experience, and Uzbekistan's ongoing transport and road infrastructure reforms. The study identifies six interconnected barrier groups: fragmented institutional mandates, underfunded and reactive maintenance systems, weak data and asset inventories, insufficient climate-resilient design, limited local participation, and procurement practices that prioritize initial cost over life-cycle performance. Results show that sustainability depends not only on technical pavement solutions but also on predictable maintenance funds, transparent prioritization, performance-based contracts, climate-risk screening, digital road asset management, and integration of rural roads with agriculture, logistics, schools, health facilities, and local enterprise development.

АННОТАЦИЯ

Устойчивая сельская дорожная инфраструктура является ключевым условием инклюзивного экономического роста, продовольственной безопасности, доступа к образованию и здравоохранению, региональной интеграции и пространственного сокращения бедности. Во многих странах сохраняется системный разрыв между строительством дорог и их долгосрочной устойчивостью. Новые сельские дороги нередко финансируются как видимые капитальные проекты, тогда как техническое обслуживание, климатическая адаптация, общественная подотчетность, контроль качества и долгосрочное управление активами получают недостаточное институциональное внимание. В статье представлен глобальный обзор системных барьеров, ограничивающих устойчивость сельской дорожной инфраструктуры, и предложена стратегическая рамка, объединяющая политику, финансирование, инженерные решения, управление и социальную инклюзию. Анализ опирается на данные Всемирного банка, инициативы Sustainable Mobility for All, Азиатского банка развития, подходы Международной организации труда к трудоемкому содержанию сельских дорог, европейские практики управления дорожными активами, опыт стран СНГ и Центральной Азии, а также реформы транспортной и дорожной сферы Узбекистана. Выделены шесть взаимосвязанных групп барьеров: фрагментация институциональных полномочий, недофинансирование и реактивный характер обслуживания, слабость данных и инвентаризации дорожных активов, недостаточное применение климатостойчивого проектирования, ограниченное участие местных

сообществ и закупочные практики, ориентированные преимущественно на первоначальную стоимость, а не на эффективность жизненного цикла. Результаты показывают, что устойчивость зависит не только от технических решений по дорожному покрытию, но и от предсказуемого финансирования обслуживания, прозрачной приоритизации, цифрового мониторинга, участия населения и интеграции дорог с аграрной экономикой, школами, медицинскими учреждениями и местным предпринимательством.

Keywords: rural roads; sustainable infrastructure; road maintenance; asset management; climate resilience; rural connectivity; life-cycle costing; transport governance; Uzbekistan; strategic framework.

Kalit soʻzlar: qishloq yoʻllari; barqaror infratuzilma; yoʻlni saqlash; aktivlarni boshqarish; iqlimga chidamlilik; qishloq aloqadorligi; hayotiy sikl qiymati; transport boshqaruvi; Oʻzbekiston; strategik asos.

Ключевые слова: сельские дороги; устойчивая инфраструктура; содержание дорог; управление активами; климатическая устойчивость; сельская связанность; стоимость жизненного цикла; транспортное управление; Узбекистан; стратегическая рамка.

1. INTRODUCTION

Rural road infrastructure is one of the most practical instruments for transforming territorial inequality into development opportunity. A rural road links farmers with input suppliers and markets, children with schools, patients with clinics, women with employment opportunities, and local producers with regional value chains. Its value is therefore not limited to transport engineering; it is a social, economic, environmental, and institutional asset. Global development practice shows that the benefits of rural roads can disappear quickly when construction is not accompanied by maintenance finance, institutional accountability, climate-resilient design, and community ownership. The central problem is systemic: many countries are able to build rural roads but struggle to keep them reliable, safe, and all-season over their design life.

International indicators confirm the scale of the issue. The Rural Access Index, used by the World Bank and reflected in the Sustainable Development Goals monitoring architecture, measures the share of rural population living within two kilometers of an all-season road. Evidence compiled in global access studies has repeatedly shown that hundreds of millions of rural people remain disconnected from reliable road networks. This access gap is not merely a physical distance problem. It also reflects seasonal isolation, poor surface condition, weak drainage, missing bridges and culverts, unsafe road geometry, insufficient maintenance equipment, and administrative fragmentation between central, regional, and local road owners.

Recent global trends make the topic more urgent. Climate change is increasing the frequency of floods, landslides, heat stress, freeze-thaw damage, erosion, and drainage overload. Rural roads are often the most exposed assets because they cross rivers, slopes, agricultural land, and low-capacity drainage systems. At the same time, agricultural modernization, rural tourism, e-commerce, health logistics, school consolidation, and emergency response require more reliable connectivity. A road that is passable only in the dry season no longer meets the needs of modern rural development. Sustainable rural road infrastructure must therefore be understood as a life-cycle system rather than a one-time construction output.

Uzbekistan's policy context demonstrates the relevance of this transition. The Development Strategy of New Uzbekistan for 2022-2026, approved by Presidential Decree No. DP-60 of 28 January 2022, places infrastructure modernization, regional development, public service access, and economic competitiveness among national priorities. The Law "On Transport" of 9 August 2021 defines the legal foundation of the transport sphere, while the Law "On Road Traffic" of 19 January 2024 establishes requirements for road design, construction, reconstruction, repair, and maintenance in compliance with normative documents. Government information from 2025

reported plans for construction and repair of 7,000 kilometers of public roads, repair of 231 bridges, gravel surfacing of 13,000 kilometers of unpaved roads, and construction of cement-concrete pavement on 400 kilometers of roads. These measures show high political attention to road infrastructure and create a basis for integrating sustainability principles into rural connectivity.

The scientific novelty of this article lies in combining global evidence on rural road sustainability with a strategic framework applicable to developing and transition economies, including Uzbekistan. The article treats barriers not as isolated technical shortcomings but as interdependent governance, finance, engineering, data, environmental, and social problems. The purpose is to identify systemic barriers to sustainable rural road infrastructure and formulate a practical framework that can support policy makers, transport agencies, local governments, researchers, and development partners.

2. METHODOLOGY

The article uses a qualitative global review methodology supported by comparative policy analysis. Sources were selected from international development institutions, road sector studies, legal acts, and scientific literature on rural access, road maintenance, transport governance, and climate-resilient infrastructure. The review covers four analytical spaces: global development literature, European asset management and life-cycle approaches, CIS and Central Asian institutional experience, and Uzbekistan's legal-policy context. This structure allows the analysis to compare mature road management models with the institutional realities of developing and transition economies.

European experience was reviewed through the lens of road asset management, preventive maintenance, safety management, and life-cycle costing. The relevance of European practice is not that it can be copied mechanically, but that it demonstrates how road networks can be managed as public assets with condition monitoring, performance indicators, maintenance standards, transparent budgeting, and risk-based prioritization. For rural roads, these principles are particularly important because low traffic volumes often make conventional economic appraisal less favorable even when social benefits are substantial.

CIS and Central Asian experience was considered because many countries in the region share inherited institutional structures, large rural territories, climate variability, and the need to modernize public procurement and local road governance. Researchers and practitioners from Uzbekistan and neighboring countries increasingly emphasize the role of transport corridors, rural accessibility, regional development, road safety, and digital public management. In Uzbekistan, work by national scholars in transport economics, regional planning, construction engineering, and public administration has highlighted the need to link road infrastructure with agriculture, logistics, employment, and local service delivery.

The methodological limitation is that the article is a strategic review rather than an empirical pavement-condition survey. It does not measure the condition of a specific road segment. Its contribution is conceptual and policy-oriented: it synthesizes evidence into a barrier typology and a strategic framework. This approach is appropriate because the sustainability of rural roads is influenced by decisions made before, during, and long after construction.

RESULTS

The first result is the identification of fragmented institutional mandates as a central barrier. Rural roads often fall between national ministries, regional administrations, municipalities, agricultural authorities, water management bodies, and local communities. When responsibility for construction, drainage, bridges, maintenance, land access, traffic safety, and environmental protection is split without clear coordination, accountability becomes weak. A road may be built by one program, damaged by another sector's drainage failure, and left without a stable

maintenance owner. Sustainable rural road policy therefore requires a clear hierarchy of road classification, ownership, funding responsibility, and performance reporting.

The third barrier is weak data. Many rural networks lack complete inventories of road length, surface type, bridge condition, drainage structures, traffic levels, school and health facility links, flood exposure, and maintenance history. Without reliable data, decisions are driven by complaints, political pressure, or equal distribution formulas rather than need, risk, and development impact. Modern approaches use geographic information systems, mobile surveys, satellite imagery, drones, community reporting, and road asset management systems. Digital tools do not replace institutions, but they make prioritization more transparent and measurable.

The fourth barrier is insufficient climate resilience. Rural roads are commonly designed using historical hydrological assumptions that may no longer be adequate. Climate-resilient rural roads require improved drainage capacity, erosion protection, slope stabilization, raised embankments in flood-prone areas, climate-appropriate materials, and maintenance plans that anticipate extreme events. Resilience is not only a design issue; it also requires emergency response protocols, risk maps, budget reserves, and local reporting mechanisms. A low-cost road that fails every rainy season is not affordable when life-cycle costs and social disruption are counted.

The fifth barrier is limited local participation and social inclusion. Rural communities often know which road sections become impassable, which culverts block water, which routes are essential for school access, and which areas are unsafe for women, children, or elderly residents. When planning ignores this knowledge, investments may miss local priorities. Labor-based and community-based maintenance models, when professionally supervised, can create local employment, strengthen ownership, and improve routine maintenance. Social inclusion also means considering disability access, school transport, emergency medical access, gendered mobility needs, and market days.

DISCUSSION

The results show that sustainable rural road infrastructure is a governance system. Engineering quality is essential, yet it cannot compensate for unstable finance, unclear mandates, poor data, or weak maintenance culture. A strategic framework must therefore connect five dimensions: policy and legal accountability, finance and life-cycle costing, resilient engineering, digital asset management, and community participation.

In policy terms, countries need an integrated rural road strategy aligned with transport, agriculture, education, health, climate adaptation, and regional development. Road classification should define who owns each road, who funds it, who maintains it, and which service level is expected. Uzbekistan's transport legislation and road traffic requirements create a legal foundation for this approach. The practical next step is to strengthen the link between national programs and district-level road asset management so that rural road decisions reflect both national priorities and local access needs.

In financial terms, maintenance should be treated as a protected investment rather than a residual expense. Road funds, local budget allocations, performance-based maintenance financing, and development partner support can be combined, but predictable routine maintenance must be guaranteed. Life-cycle costing should be mandatory for comparing gravel, asphalt, cement-concrete, stabilized soil, and other pavement options. The cheapest construction option may become the most expensive if it requires frequent reconstruction after floods, heavy agricultural traffic, or poor drainage.

In engineering terms, rural road design should be context-sensitive. Low-volume roads do not always require expensive pavement, but they require good drainage, appropriate geometry, durable materials, and maintainable structures. Climate screening should be applied at the planning stage. Bridges and culverts deserve special attention because a single failed crossing can isolate an entire

village. Preventive maintenance standards should specify inspection intervals, drainage cleaning, shoulder repairs, pothole treatment, grading frequency, and emergency response responsibilities.

In digital management terms, a rural road asset management system should contain inventory, condition, traffic, risk, and expenditure data. The system should be simple enough for local authorities to update but robust enough to guide national budgeting. Indicators may include share of rural roads in good or fair condition, number of communities with all-season access, distance to schools and health facilities, flood-prone kilometers, maintenance backlog, and response time after extreme weather. Public dashboards can strengthen transparency and reduce arbitrary prioritization.

In social terms, rural road sustainability improves when communities participate in planning and monitoring. Local residents can report drainage blockage, pavement damage, unsafe crossings, and contractor non-compliance. Community engagement should not replace professional engineering, but it can improve targeting and accountability. Employment-intensive maintenance can be useful where unemployment is high and tasks are suitable for local labor, especially for routine activities such as vegetation control, drainage cleaning, shoulder maintenance, and minor repairs.

STRATEGIC FRAMEWORK

The proposed strategic framework contains seven mutually reinforcing pillars. The first pillar is legal clarity: every rural road must have a defined owner, maintenance authority, financing source, and service-level standard. The second pillar is life-cycle finance: planning documents should include construction, routine maintenance, periodic maintenance, climate adaptation, and emergency repair costs. The third pillar is resilient design: drainage, materials, embankments, bridges, and slopes must reflect climate risk and local environmental conditions.

The fourth pillar is digital asset management: all rural roads should be mapped, classified, and monitored through a practical database connected with budgeting. The fifth pillar is transparent prioritization: investment decisions should combine technical condition, population served, access to schools and clinics, agricultural productivity, poverty indicators, disaster risk, and local demand. The sixth pillar is performance-based delivery: procurement should reward quality, durability, timely maintenance, and service outcomes rather than only low initial price. The seventh pillar is community accountability: citizens, mahalla institutions, farmers, schools, and health facilities should be able to participate in identifying priority links and monitoring service quality.

CONCLUSION

Sustainable rural road infrastructure is a foundation for inclusive development, but its sustainability depends on more than building kilometers of road. The global review shows that rural road failure is usually produced by systemic weaknesses: fragmented responsibilities, insufficient maintenance finance, weak asset data, climate-vulnerable design, limited local participation, and procurement systems focused on short-term costs. These barriers interact with one another. A technically good road can deteriorate quickly if drainage is not maintained; a well-funded program can underperform if road selection is not transparent; a climate-resilient design can fail if local institutions do not inspect and repair assets after extreme weather.

The article argues for a shift from project-based rural road construction to life-cycle rural connectivity management. This means that the purpose of road policy should not be limited to completing construction works, but should include reliable all-season access, safety, resilience, affordability, and social value throughout the road's design life. The strategic framework proposed in this article integrates legal clarity, life-cycle finance, resilient engineering, digital asset management, transparent prioritization, performance-based delivery, and community accountability. These pillars are not separate reforms; they are a single system for protecting public investment and expanding development benefits. Strategic framework for sustainable rural road infrastructure

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