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LIFECYCLE-BASED INFRASTRUCTURE PLANNING IN GEORGIA: MODELLING EFFICIENCY IN ROAD MAINTENANCE AND REHABILITATION

D. KESHELAVA, G. MZHAVANADZE, Y. BABYCH

Davit Keshelava[1], Giorgi Mzhavanadze[2], Yaroslava Babych[3]
[1 2 3] ISET Policy Institute, Georgia
[1] https://orcid.org/0000-0002-1513-1447, E-mail: d.keshelava@iset.ge
[2] https://orcid.org/0000-0002-0336-311X, E-mail: g.mzhavanadze@iset.ge
[3] https://orcid.org/0000-0002-6216-361X, E-mail: y.babych@iset.ge

Abstract: *This article develops and applies a stylized theoretical model of infrastructure lifecycle management to the Georgian road network, with the aim of identifying cost-efficient strategies for balancing investment, maintenance, and rehabilitation. The main scientific contribution lies in adapting established optimization models, such as the resurfacing framework and the marginal benefit-cost ratio principle, to the context of an emerging economy with fiscal and institutional constraints. The paper formalizes a deterministic deterioration model that minimizes the present value of total lifecycle costs by incorporating agency costs and user costs as functions of road quality and intervention thresholds. The model accommodates fiscal rigidity by quantifying the cost of deferral under fixed maintenance budgets. Empirically, the paper presents a novel classification and analysis of infrastructure spending in Georgia from 2014 to 2024, highlighting persistent underinvestment in maintenance and frequent misclassification of rehabilitation as capital investment. The study benchmarks these patterns against international good practices. By combining theoretical innovation with policy-relevant empirical evidence, the paper provides a framework for lifecycle-based infrastructure planning that can be adapted for use in other developing countries.*

Keywords: *Infrastructure lifecycle; road maintenance; rehabilitation; investment efficiency; pavement deterioration; Georgia; cost minimization; public investment management*

INTRODUCTION

The efficiency of infrastructure spending has increasingly drawn attention from policymakers and international institutions, particularly in the context of public investment management. The issue is not limited to the scale of investment but extends to the quality and timing of asset maintenance over the infrastructure lifecycle. According to the IMF, inefficiencies in planning, procurement, and governance can result in the loss of up to one-third of public infrastructure investment (Schwartz et al., 2020). The United Nations has similarly warned that a bias toward new construction at the expense of maintenance may lead to infrastructure decay and suppress GDP growth by as much as 2% per year in developing countries (United Nations, 2021).

This problem is especially pronounced in countries like Georgia, which aspires to function as a regional transit and logistics hub. Despite receiving significant donor funding for road infrastructure, Georgia lacks a comprehensive framework for managing assets across their full lifecycle. The IMF's Public Investment Management Assessment (PIMA) notes that investment decisions in Georgia are often guided by visibility and short-term considerations, while maintenance and rehabilitation receive insufficient attention (IMF, 2018). The treatment of maintenance as current expenditure under standard public accounting frameworks further discourages timely intervention, as it reduces measured savings, unlike capital expenditures which enhance reported investment (Babych & Leruth, 2021).

Economic models of infrastructure lifecycle management consistently emphasize the value of timely maintenance. Deterministic frameworks such as those developed by Harvey (2012) and Li and

Madanat (2002) demonstrate that deferring maintenance increases user costs disproportionately, while periodic interventions can reduce total lifecycle costs. More complex formulations explore the interaction between infrastructure quality and road user behavior under network competition (De Palma, Kilani & Lindsey, 2007). However, these models are primarily tailored to high-income settings and do not account for the fiscal and institutional constraints typical for low- and middle-income countries. This study addresses this gap by applying a stylized theoretical model to the Georgian road network. It assumes fixed traffic flows, deterministic deterioration, and maintenance triggered by pavement roughness thresholds (e.g., International Roughness Index (IRI)). The model aims to minimize the present value of both agency and user costs. The empirical analysis uses budget data and project records from 2014-2024 to assess spending patterns across construction, rehabilitation, and maintenance. International practices are used as benchmarks. The paper concludes with reform proposals for budgeting and asset management to improve cost-efficiency and transparency.

THEORETICAL FOUNDATIONS

A large body of literature addresses the optimization of infrastructure maintenance, rehabilitation, and investment. While most models were developed for high-income countries with stable institutions and robust data systems, their insights remain relevant for emerging economies, particularly regarding lifecycle cost trade-offs.

A key concept in this field is infrastructure deterioration over time due to usage, climate, and material wear. For roads, this is measured as progressive surface roughness, affecting comfort, safety, and vehicle operation. Paterson and Attoh-Okine's framework models deterioration as a function of structural deformation, surface defects, and environmental stress (Paterson & Attoh-Okine, 1992). Their work underpins systems like the World Bank's HDM-4, widely used for road asset management.

Economic models built on such deterioration laws aim to minimise total costs - agency costs (e.g., resurfacing) and user costs (e.g., travel time, vehicle wear). Harvey presents a deterministic model where the optimal timing of maintenance balances the cost of intervention against rising user costs from deferred works. This approach introduces the marginal benefit-cost ratio as a decision rule (Harvey, 2012). Li and Madanat (2002) advance this by modelling continuous deterioration under a Markov process. Their resurfacing policy defines intervention thresholds to maintain pavement within acceptable roughness bounds. The model remains effective even under stochastic variation in road conditions (Li & Madanat, 2002).

Newbery's (1988) contribution focuses on road damage externalities. He shows that when roads are resurfaced at a defined threshold, the average maintenance cost equals the marginal social cost of road use. This supports using average maintenance cost as a basis for road user charges (Newbery, 1988). De Palma, Kilani, and Lindsey (2007) examine competing roads in a duopoly setting. Their model links maintenance and service quality to user utility. They find that in unregulated competition, maintenance may be underprovided, especially on higher-quality routes - highlighting the importance of public oversight (De Palma, Kilani & Lindsey, 2007).

Though calibrated in high-income contexts, these models can be adapted to resource-constrained settings. Their core insight is that timely, cost-effective maintenance reduces long-term expenditure remains applicable and will guide the analysis in subsequent sections.

EMPIRICAL AND POLICY STUDIES

Translating theoretical models into practice requires empirical validation and alignment with budgetary and institutional realities. In many developing and transition economies, maintenance remains underfunded, resulting in inefficient use of infrastructure investment.

A global review by Schwartz et al. found that up to one-third of public infrastructure investment is lost to inefficiencies, mainly due to inadequate asset management and neglected maintenance. Their analysis of over 2,000 projects shows that countries with stronger investment management systems achieve better returns not by spending more, but by managing assets more effectively (Schwartz et al., 2020). The 2021 United Nations Handbook reinforces this view, warning that prioritizing visible new projects over maintenance may cost low- and middle-income countries up to 2% of GDP annually. The report recommends institutionalizing asset management, adopting lifecycle-based budgeting, and ensuring stable funding for maintenance (United Nations, 2021). Georgia's 2018 PIMA report identified several weaknesses: fragmented maintenance responsibilities, limited project appraisal, and the absence of lifecycle cost analysis. Despite increased investment in roads, maintenance and rehabilitation remain poorly prioritized, threatening the durability of past capital works (IMF, 2018).

Babych and Leruth argue that standard budget classifications contribute to this problem. Maintenance is recorded as current expenditure, while construction and major rehabilitation are treated as investment. This skews incentives against preventive spending and distorts fiscal planning. They propose a separate classification for rehabilitation to enhance transparency and efficiency (Babych & Leruth, 2021). Although focused on buildings, a literature review by Le et al. (2018) offers relevant insights. They find both under- and over-spending on maintenance can be inefficient and stress the need for empirical benchmarks and better data on asset condition, usage, and costs - needs that are equally pressing in transport infrastructure (Le et al., 2018). These studies highlight the importance of adapting theoretical frameworks to local institutional and fiscal contexts. Without improved data systems and classification standards, countries risk misallocating resources across the asset lifecycle.

INTERNATIONAL BENCHMARKS AND PRACTICES

International experience shows that efficient allocation between new construction, rehabilitation, and maintenance depends on the alignment of budgeting systems, expenditure classifications, and investment planning frameworks. High-performing systems apply lifecycle cost principles, supported by data and clear institutional rules.

Estonia provides a strong example. According to the IMF's 2019 PIMA, the country separates maintenance, rehabilitation, and construction in both budgeting and accounting. Medium-term ceilings are set specifically for maintenance, and asset registers are routinely updated using physical condition indicators (IMF, 2019).

Chile uses performance-based contracts to enforce road maintenance standards. Under its National Infrastructure Fund, contracts include measurable criteria such as pavement roughness thresholds, with penalties for non-compliance. A robust inspection regime supports long-term asset quality. This model has influenced PPP frameworks across Latin America (Guasch et al., 2014).

Mexico links investment and maintenance funding to performance indicators. Transport agencies apply multi-year asset management plans and conduct regular audits. A 2017 OECD report highlights efforts to harmonize expenditure definitions between federal and local governments to reduce classification inconsistencies (OECD, 2017).

Poland's General Directorate for National Roads and Motorways operates a pavement management system based on the HDM-4 platform. Projects are prioritized using indicators like the IRI and evaluated through net present value (NPV) and internal rate of return (IRR) calculations. This supports transparent, cost-effective programming (Pieriegud & Archutowska, 2012).

Despite institutional differences, these systems share key features: clear classification standards, condition-based planning, medium-term expenditure frameworks, and performance-linked funding. For Georgia, where maintenance is underfunded and rehabilitation is often misclassified, these cases offer valuable lessons. Aligning national practice with international benchmarks would require better asset data, revised budget coding, and strengthened institutional accountability.

CONCEPTUAL FRAMEWORK

Efficient infrastructure management requires a lifecycle perspective that captures trade-offs between investment, maintenance, and rehabilitation. This is especially important in fiscally constrained settings, where new construction often overshadows the need for preserving existing assets. Effective infrastructure management requires a structured approach to evaluating the long-term cost implications of alternative spending strategies. This is especially relevant in contexts where fiscal space is constrained, and public attention remains focused on new construction rather than asset preservation.

A lifecycle-based framework allows for balancing investment, maintenance, and rehabilitation by accounting for the progressive deterioration of infrastructure. For road networks, condition is typically assessed using metrics such as the IRI or Pavement Condition Index (PCI) (Haas, Hudson & Zaniewski, 1994). Infrastructure quality declines with age, traffic volume, and environmental exposure. As conditions deteriorate, user costs (including travel delays, increased vehicle operating expenses, and safety risks) tend to rise non-linearly. Agency costs vary depending on the type and timing of intervention: routine maintenance is relatively inexpensive but requires regular application, while delayed interventions may result in costly rehabilitation or full reconstruction (Burningham & Stankevich, 2005).

The deterioration process is well illustrated in Paterson's foundational model, incorporated into the HDM-4 platform, which shows that roughness initially increases slowly but accelerates after a critical threshold (e.g., IRI > 5). Beyond this point, user costs escalate rapidly, and major rehabilitation becomes unavoidable (Paterson, 1987). Delayed maintenance not only increases long-term costs but also raises fiscal risk and the likelihood of structural failure, particularly for high-risk assets such as bridges and mountain roads (NCHRP, 2011).

The lifecycle optimization objective can be formally expressed as minimizing the present value of total costs over a defined time horizon T:

$$min \int_0^T \left[C_m(t) + C_u\big(q(t)\big)\right] e^{-rt} dt \qquad (1)$$

where $C_m(t)$ is the agency (maintenance or rehabilitation) cost at time t, $C_u(q(t))$ is the user cost as a function of road quality $q(t)$, and r is the discount rate. The system evolves under a known deterioration function $dq/dt = -\delta(q)$, which reflects roughness progression or structural degradation. This model captures the essential trade-off: frequent interventions reduce user costs but require higher annual budgets, while infrequent or delayed interventions defer costs but result in greater long-term liabilities.

Translating this into policy requires setting quality thresholds, identifying intervention types, and applying cost parameters. In low-data environments, engineering assumptions and unit price catalogues, such as those in HDM-4, enable approximate lifecycle estimates (PIARC, 2023).

Institutional factors also matter. As IMF and World Bank reports show, treating maintenance as current expenditure and rehabilitation as capital investment creates bias toward new construction (Haas, Hudson & Zaniewski, 1994; Burningham & Stankevich, 2005). This model provides a basis to assess such misalignments and supports reforms for lifecycle-based budgeting in Georgia.

THEORETICAL MODEL STRUCTURE

Building on the framework outlined above, this section sets out a stylized theoretical model to guide maintenance and investment planning for road infrastructure in settings where fiscal and institutional constraints are binding. The model reflects principles established in the resurfacing optimisation literature, particularly the deterministic, steady-state formulation by Li and Madanat (2002).

Infrastructure quality over time is represented by the differential equation:

$$dq(t)\ /\ dt = -\delta\big(q(t)\big) \qquad (2)$$

where $q(t)$ is the infrastructure quality (e.g., inverse of IRI or PCI) at time t, and $\delta(q)$ is the deterioration rate, which may be constant or dependent on factors such as traffic load, climate, and construction quality. In most practical applications, a linear or exponential form of deterioration is assumed for computational tractability (Prozzi & Madanat, 2004).

The model assumes that once the infrastructure quality falls below a predetermined threshold q_min, a resurfacing action is applied, restoring the asset to a higher quality level q_max. This cyclical intervention structure reflects common maintenance planning logic in pavement management systems.

The optimal resurfacing policy involves choosing the threshold *q_min* and restoration intensity *Δq* to minimize the present value of total costs over an infinite time horizon:

$$min \sum_{n=1}^{\infty} \left[C_m(q_n) + \int_{tn}^{n+1} C_u\left(q(t)e^{-r(t-t_0)}\right) t \right] \quad (3)$$

where $C_m(q_n)$ is the agency cost of resurfacing at time t_n, $C_u(q(t))$ is the user cost as a function of road quality, and r is the social discount rate. A key insight from this model is that the optimal intervention cycle is not fixed but depends on the cost elasticity of quality and the deterioration dynamics of the asset.

The model accommodates extensions: multiple intervention types, stochastic deterioration, and variable traffic. Even in reduced form, it shows that resurfacing at higher thresholds may lower user costs, despite increased agency spending - a finding supported by HDM-4 applications.

In Georgia's context, the model can be calibrated using unit cost catalogues and traffic data. Thresholds such as IRI = 3 for overlays or IRI = 5 for rehabilitation are consistent with national and World Bank practice (Burningham, S. & Stankevich, 2005).

Importantly, the model also enables quantifying the costs of deferred maintenance under budget constraints - conditions often present in rigid, line-item budgeting systems. It can be used to assess the efficiency losses from delayed interventions and support arguments for reforming budget classification and expenditure rules. Sensitivity analysis further enhances its policy relevance. Parameters such as the discount rate, traffic growth, or cost inflation can be varied to test the robustness of maintenance strategies. In doing so, the model becomes a tool not only for planning but also for fiscal risk assessment and institutional reform in infrastructure management.

GEORGIA'S ROAD NETWORK: COVERAGE, QUALITY INDICATORS, AND GAPS

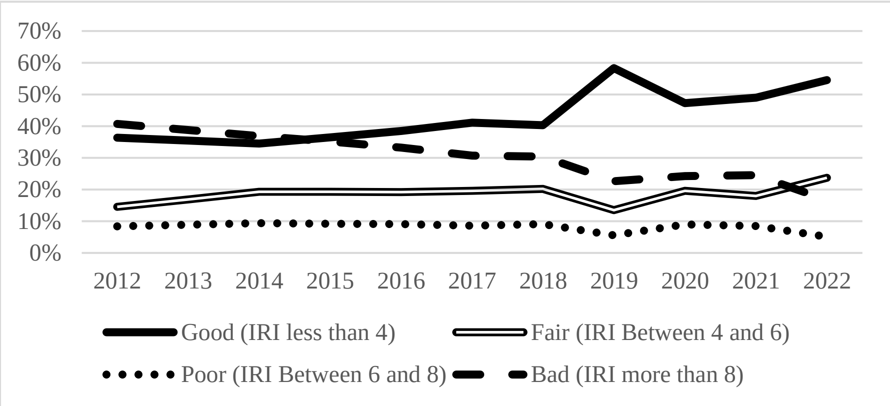
According to the latest available data from 2023, Georgia's road network comprises 34,043.9 km of *local roads*, 5,460.3 km of *secondary roads*, and 1,593.4 km of *international roads*. In total, this corresponds to a road density of 589.6 km per 1,000 km² (Department of Roads and Municipal Administration, 2024) (Local roads exclude those within self-governing cities, in line with the 2021 amendment to the Law of Georgia "On Motorways."). While comprehensive data on road quality remain limited, available indicators provide some insight into the state of the network. Based on the World Economic Forum's Global Competitiveness Index, which reflects perceptions of road quality (GCI 4.0: Quality of roads (1-7) based on survey), Georgia ranked between 80th and 81st globally during 2017–2019. Over this period, its score improved from 45.9 in 2017 to 46.6 in 2019 (WEF, 2019). Georgia outperformed other South Caucasus countries and several Eastern European economies, including Latvia (95th), Serbia (98th), Bulgaria (102nd), North Macedonia (105th), Ukraine (114th), Romania (119th), Bosnia and Herzegovina (121st), and Moldova (129th) (WEF, 2019). Nonetheless, Georgia still lags behind the leading performers in both Eastern and Western Europe in terms of perceived road quality.

In addition to international benchmarks, domestic data provided by the Roads Department of Georgia offer a more detailed picture of road surface quality based on the International Roughness Index (IRI). As of 2020, 89% of *international roads* were assessed to be in good or fair condition (IRI < 6), while 7% were categorized as poor (IRI between 6 and 8) and 4% as bad (IRI > 8). The Department aims to improve these figures further, targeting an increase in the share of roads in good or fair condition to 95% by the end of 2025 and 97% by 2030, while reducing the share of roads in bad condition to 1% and 0%, respectively (Transport Community, 2023). While the overall condition of international roads shows a positive trend, a considerable number of road sections still require rehabilitation and periodic maintenance to preserve service quality and prevent accelerated deterioration.

The condition of *secondary roads* remains more challenging. In 2020, only 67% of secondary roads were classified as being in good or fair condition, while 9% were in poor condition and 24% in bad condition. The planned targets anticipate a gradual improvement, with the share of roads in good and fair condition expected to rise to 79% by 2025 and 93% by 2030. Correspondingly, the proportion of roads in bad condition (IRI > 8) is projected to fall to 14% in 2025 and further to just 4% by 2030 (Transport Community, 2023).

Notably, the share of secondary roads in good condition (IRI < 4) has shown consistent growth, surpassing the share of roads in bad condition in 2015 and accelerating markedly since 2018. Meanwhile, the proportion of secondary roads in fair condition (IRI between 4 and 6) and poor condition has remained relatively stable over time (see Figure 1). Nevertheless, even by 2022, only slightly more than half of the road network was in good condition, while more than 16% of secondary roads remained in bad condition (Transport Community, 2023).

Figure 1. *Secondary Road Network Condition 2012–2022 (GEL Million)*
Source: Transport Community (2023), SSA Roads Department of Georgia



Note: Data for 2022 are based on estimates and may be subject to revision.

There is currently no publicly available data on the condition of *local roads* in Georgia beyond 2010. The most recent assessment, conducted by the World Bank that year, offers important historical context. At the time, only 5% of local roads were classified as being in good condition, 10% in fair condition, another 10% in poor condition, and the remaining 75% in bad condition. This extremely poor state of the local road network was largely the result of prolonged neglect following independence, during which many roads received little to no maintenance for over a decade.

Although local maintenance practices have improved in recent years, the legacy of underinvestment continues to weigh heavily on the system. As of the latest available qualitative assessments, only a small share of local roads—mainly those rehabilitated under the World Bank's Secondary and Local Roads Project (SLRP) and similar programs—is considered to be in good condition. Approximately three-quarters of the local road network remains in bad condition, underscoring a significant disparity compared to the relatively better-maintained international and secondary road networks (World Bank, 2010).

RESILIENCE AT RISK: RISING PRESSURE ON GEORGIA’S ROAD INFRASTRUCTURE FROM MOBILITY AND CLIMATE CHANGE

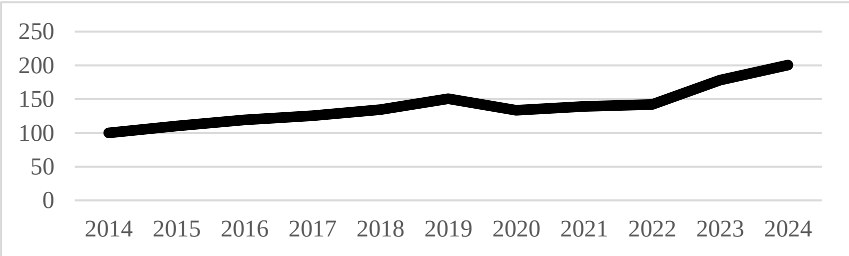
In addition to the notable improvements in the overall condition of Georgia’s road network—particularly on international roads—significant challenges persist with regard to secondary and, more acutely, local roads. These challenges are likely to intensify in the coming years due to a combination of environmental factors and increased traffic volumes, both of which heighten the importance of timely and adequate road maintenance. According to the Ministry of Internal Affairs, the number of registered vehicles in Georgia has risen sharply over the past seven years, increasing from approximately 1.2 million in 2017 (around 330 per 1000 persons) to nearly 1.8 million in 2024 (around 480 per 1000 persons) (Geostat, 2024). The increase was heavily concentrated in Tbilisi, which accounted for 22.2 percentage points of the total growth, followed by Imereti (4.5 ppts), Kakheti (4.0 ppts), Kvemo Kartli (3.7 ppts), Adjara (2.7 ppts), and Shida Kartli (2.3 ppts) (Geostat, 2024).

This growth in the vehicle fleet has translated into higher usage intensity on major transport corridors, particularly international roads. To assess infrastructure stress over time, a Road Pressure Index (RPI) was constructed, weighting vehicles by their estimated impact on road wear. The index is defined as:

$$RPI_t = \frac{\sum_i (V_{i,t} * W_i)}{L_t} \quad (4)$$

where $V_{i,t}$ - number of registered vehicles of type i in year t (e.g., cars, minibus, bus and truck, trailer and 3 axles or more vehicle), W_i - weight factor for vehicle type i, capturing its relative road pressure/damage, L_t - total road length in year t (in km). The weights reflect the relative impact of each vehicle type on road deterioration based on axle load and wear intensity. The resulting index measures the weighted vehicle load per kilometer of road and is normalized using base-year indexing (e.g., 2010 = 100) to facilitate trend analysis. The RPI shows a clear upward trajectory since 2014, with the only decline observed in 2020 during the COVID-19 pandemic. Notably, road pressure has intensified since 2022, reflecting increased cargo flows through the Middle Corridor and a surge in economic activity. This trend underscores the urgent need for enhanced and proactive road maintenance planning (Roads Department of Georgia, 2024).

Figure 2. *Road Pressure Index (RPI) 2014–2024 (2014 as a Base Year)*



Source: Authors' Calculations, Statistics Office of Gergia, Road Department of Georgia

Furthermore, Georgia's road network has faced increasingly frequent damage from climate-related hazards over the past decade. Intensifying extreme rainfall has led to floods and mudflows that wash out bridges and road foundations, especially in mountainous areas (Government of Georgia, 2017). For example, the June 2015 Tbilisi floods caused over $20 million in damages, destroying sections of at least 40 roads in the capital (World Bank, 2017). In Georgia's highlands, heavier precipitation has triggered more landslides and debris flows. In 2014, massive landslides in the Dariali Gorge repeatedly blocked the only highway to Russia for weeks, wrecking road infrastructure and even severing a transnational gas pipeline (Civil Georgia, 2014). Such events are not isolated. National statistics indicate that landslide incidence has risen by roughly 63% since the late 1980s, a trend attributed to changing climate patterns (PPIAF, 2020). Meanwhile, heatwaves and rising average temperatures have begun to degrade pavement integrity, with higher summer heat accelerating asphalt deterioration (GIZ, 2020). These physical impacts underscore the growing vulnerability of Georgia's roads to climate change and associated environmental shifts. The rising number of vehicles and the associated increase in road pressure as well as environmental damages underscore the growing importance of routine maintenance to preserve road quality over time. Ensuring adequate and timely maintenance reduces the risk of premature deterioration, thereby lowering the need for costly rehabilitation works or the early reconstruction of road segments.

TRENDS IN ROAD INFRASTRUCTURE SPENDING IN GEORGIA: CONSTRUCTION VS. MAINTENANCE (2014–2024)

Over the past decade, Georgia has experienced a substantial expansion in investment activity, with Gross Fixed Capital Formation (GFCF) increasing by 1.7 times in real terms between 2014 and 2024 (Geostat, 2024). Although private sector investment has remained the dominant force, public investment has played a strategically important role, consistently contributing around one-third of total capital formation. Capital project expenditures financed through the state budget quadrupled over the same period—rising from 12% to 16.6% of total budgetary outlays and reaching nearly 4.3 billion GEL by 2024 (Geostat, 2024; Ministry of Finance, 2024). When measured as a share of GDP, public capital spending grew from just under 4% to 4.7%, highlighting a sustained policy orientation toward infrastructure-led development (Ministry of Finance, 2024). At the same time, the composition of investment financing shifted markedly, with the share of domestic sources increasing from 40.8% in 2014 to 70.9% in 2024—signaling improved domestic revenue mobilization and declining reliance on foreign grants (Ministry of Finance, 2024). Within this evolving public investment landscape, road infrastructure has emerged as a central priority, absorbing an increasing share of public resources and anchoring Georgia's ambitions to strengthen its role as a regional transit and connectivity hub. In 2024, 70.9% of capital project expenditures were financed through domestic budget funds, 28.5% through external loans, and only 0.6% through grants (Ministry of Finance, 2024).

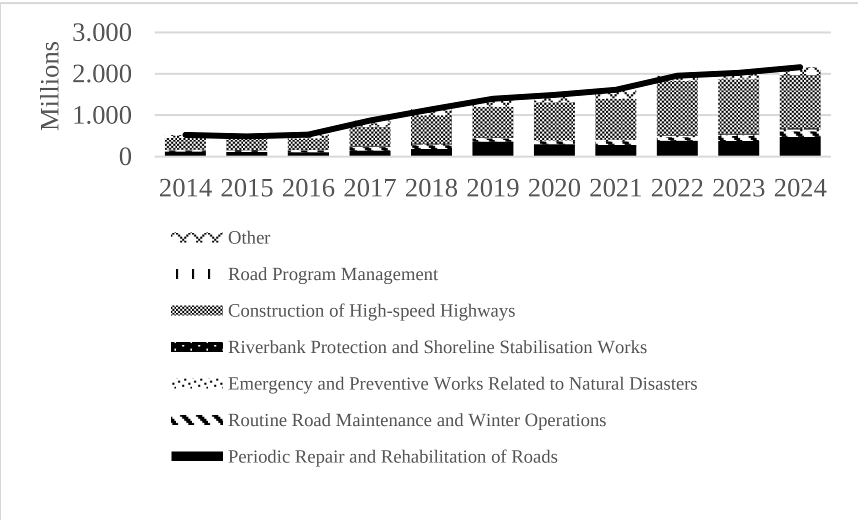
Between 2014 and 2024, the Roads Department of Georgia expanded its spending from 0.5 billion GEL to over 2.1 billion GEL on road infrastructure improvement measures (Roads Department of Georgia, 2024). This extraordinary increase reflects a compound average growth rate of 16.6% per year. The expansion was not smooth; it featured pronounced spikes in budget expenditures – notably 64.9% growth in 2017, followed by 31.0% in 2018, 21.9% in 2019, and 21.2% in 2022 (Roads Department of Georgia, 2024). These surges correspond to periods of accelerated project implementation (e.g. the scaling up of major highway construction programs), highlighting the volatility and project-driven nature of Georgia's road investment cycle. In terms of the broader economy, annual road infrastructure expenditure has fluctuated between 1.4% and 3% of GDP over the decade (Roads Department of Georgia, 2024; Geostat, 2024). This elevated spending aligns with Georgia's strategic emphasis on developing transport corridors – an ambition to serve as a regional transit hub that attracted substantial donor financing for new highways. Crucially, however, the rising expenditure has not translated into a proportional increase in upkeep of existing assets. As the IMF's Public Investment Management Assessment (PIMA) observed, maintenance and rehabilitation remain poorly prioritized despite greater outlays, posing risks to the durability of past investments. This suggests that spending quality – the balance between building new infrastructure and preserving old – may be as important as spending quantity in Georgia's road sector (IMF, 2018).

Georgia's road infrastructure budget is officially divided into three programmatic components: (1) *Road Program Management* (administration and planning), (2) *Construction and Maintenance of Roads*, and (3) *Construction of High-Speed Highways*. In practice, the lion's share of resources has been absorbed by new construction, especially highways, while maintenance activities constitute a relatively small portion of the total. In 2014, for example, the construction of high-speed highways program accounted for 283 million GEL, or 53.8% of total road infrastructure spending (Roads Department of Georgia, 2024). By 2024, this category had grown to over 1.2 billion GEL, representing 58.9% of the road budget (Roads Department of Georgia, 2024). The predominance of high-speed highway projects reflects Georgia's focus on expanding its main transit corridors, often with external funding support. This prioritization of new highway construction is further evidenced by the budget's evolution: the highway program consistently grew faster than other components, increasing not only in absolute terms but also as a share of an expanding pie.

Correspondingly, the resources devoted to road maintenance and rehabilitation have risen in absolute terms yet lag behind in relative growth. Under the *Construction and Maintenance of Roads* umbrella, two key line-items are *Periodic Repair and Rehabilitation* (i.e. major scheduled renewals of road pavement) and *Routine Maintenance and Winter Operations* (everyday upkeep such as pothole patching, cleaning, and snow removal). The Construction and Maintenance of Roads budget category encompasses a range of activities, including Periodic Repair and Rehabilitation, Routine Maintenance and Winter Operations, as well as Emergency and Preventive Works related to natural disasters, riverbank protection, and shoreline stabilization. Among these, Periodic Repair and Rehabilitation and Routine Maintenance and Winter Operations represent the largest subcomponents.

In 2014, periodic repair and rehabilitation received slightly more than 119 million GEL, which was 22.7% of total road infrastructure expenditure (approximately 0.4% of GDP) and 50.4% of expenditures on construction and maintenance of roads (Roads Department of Georgia, 2024; Geostat, 2024). Routine maintenance and winter operations in 2014 was funded at just under 37 million GEL (about 7% of the road infrastructure improvement budget, 15.5% of the expenditures on construction and maintenance of roads, and 0.1% of GDP) (Roads Department of Georgia, 2024; Geostat, 2024). By 2024, these allocations had increased to over 481 million GEL for periodic rehabilitation (about 22.3% of the total road infrastructure improvement budget, 54.9% of the expenditures on construction and maintenance of roads, and 0.5% of GDP) and around 125 million GEL for routine maintenance (about 5.8% of the total road infrastructure improvement budget, 14.4% of the expenditures on construction and maintenance of roads, 0.1% of GDP) (Roads Department of Georgia, 2024; Geostat, 2024). Thus, over the decade the nominal spending on maintenance nearly quadrupled, yet its share of both the road budget and GDP barely changed. In fact, routine maintenance saw a slight decline in budget share (from 7.0% to 5.8%), while periodic rehabilitation held roughly constant around 22–23% (Roads Department of Georgia, 2024). This indicates that new capital works have outpaced maintenance even as overall funding grew. The composition of spending therefore reinforces a construction-heavy pattern: roughly 60% of funds go to new highways by 2024, whereas the combined outlay on periodic rehabilitation and routine maintenance hovers near 28% (with the remainder going to program management and other minor works) (Roads Department of Georgia, 2024). The evidence clearly points to a persistent imbalance: Georgia's road investment strategy has heavily favored building new infrastructure over adequately maintaining the existing network (see Figure 3).

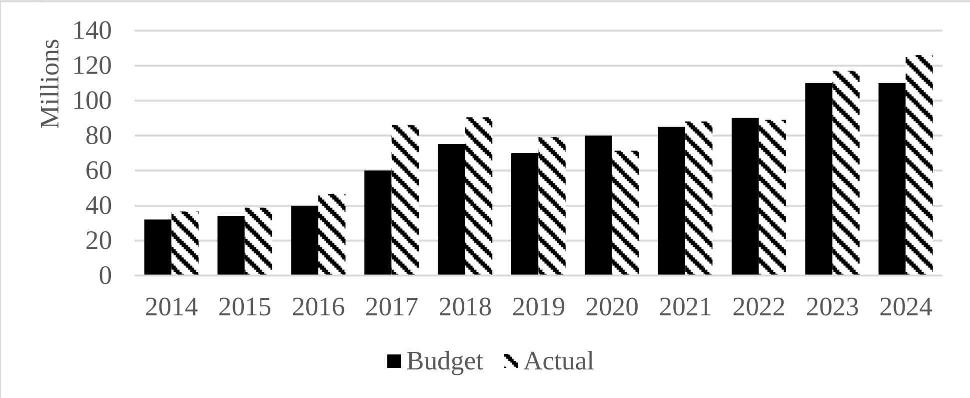
Figure 3. *Decomposition of the Road Infrastructure Improvement Measures 2014–2024 (GEL Mil.)*



Source: SSA Roads Department of Georgia

In the road sector, both current and capital maintenance are budgeted through specifically designated programs and sub-programs. The Roads Department employs its own methodology to estimate physical maintenance needs, using a multi-criteria analysis based on maintaining defined road condition standards, typically measured by the International Roughness Index (IRI) (World Bank, 2010). However, there is no unified or standardized approach for calculating either routine or capital maintenance requirements and their corresponding budgetary implications. In practice, funding levels are determined largely through incremental adjustments, reflecting the availability of fiscal resources rather than a needs-based assessment. The analysis of maintenance-related expenditures—both planned and actual—is further complicated by limited budgetary disaggregation. While routine maintenance appears under road project and equipment classifications, spending on capital maintenance is not consistently identified or separately reported in budget execution documents (World Bank, 2010). Available data indicate that actual maintenance expenditures have generally exceeded approved allocations—except in 2020, when spending was temporarily constrained by the COVID-19 pandemic (Roads Department of Georgia, 2024) (see Figure 4).

Figure 4. *Routine/Periodic Maintenance Spending on Roads 2014–2024 (GEL Million)*

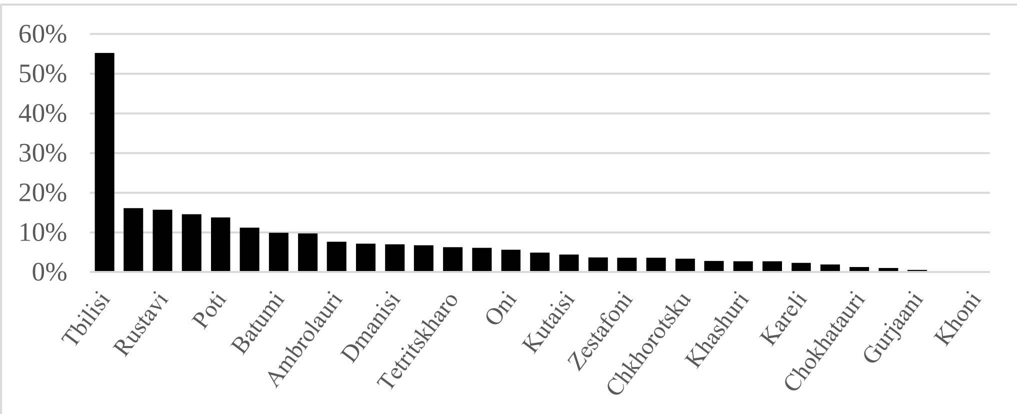


Source: SSA Roads Department of Georgia

In 2007, responsibility for local road maintenance in Georgia was transferred from the Roads Department to municipalities, introducing a decentralized framework. However, many municipalities continue to face institutional and financial constraints, with limited experience in managing maintenance operations. As a result, they rely heavily on private contractors not only for implementation but also for drafting contracts and workplans (World Bank, 2010). Most contractors are former Roads Department units privatized in the late 1990s. While some have acquired new equipment for rehabilitation, most rely on aging machinery. Routine maintenance plays a minor role in their business—typically 5–10% of turnover—but is valued for its stability, particularly during off-peak seasons. Contractor turnover remains low, and contracts are often awarded to the same firms due to weak municipal procurement capacity (World Bank, 2010).

Routine maintenance is funded exclusively from municipal revenues, as no earmarked transfers are provided by the central government. Although periodic rehabilitation may receive co-financing, routine maintenance allocations vary widely across municipalities. In 2022, only Tbilisi allocated more than 50% of its road infrastructure budget to maintenance—up from 34.9% in 2018. A few others, including Ozurgeti, Rustavi, Dusheti, Poti, and Akhalkalaki, allocated slightly more than 10%, while Batumi was close to that level. Several municipalities reported no maintenance expenditure at all, prioritizing construction and rehabilitation. For some, data remains unavailable (Ministry of Finance, 2024) (see Figure 5).

Figure 5. *The Share of Road Infrastructure Maintenance Expenditures Within Total Road Infrastructure Development Spending 2022 (%)*



Source: Authors' Calculations Based on Municipal Budget Documents

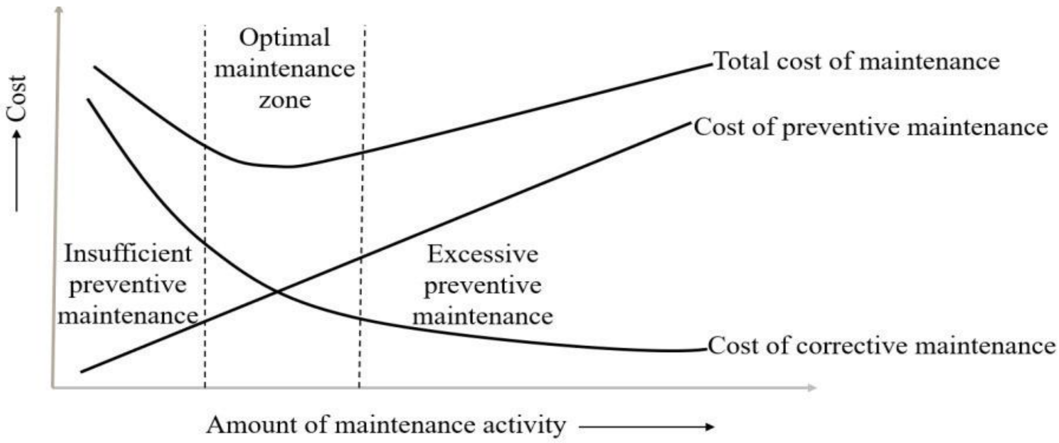
Routine road maintenance plays a critical role in preserving infrastructure quality and managing long-term costs. According to a World Bank assessment from 2010—the most recent available detailed breakdown—routine maintenance expenditures for international and secondary roads were primarily directed toward winter road maintenance (51.9%), followed by roadway maintenance (32.6%), technical means of traffic regulation (9.3%), and road structure maintenance (3.5%) (World Bank, 2010). The distribution differs markedly in the case of local roads, where the emphasis shifts toward basic upkeep: roadway maintenance accounts for 66.5%, structural maintenance 21.2%, and traffic regulation measures just 5.7%. Winter road maintenance comprises only 3.3%, largely due to limited municipal budgets and prioritization of pavement repairs. Over 65% of the local road maintenance budget is allocated to road surface improvements—most notably, patching and sealing of asphalt roads (40%), graveling of non-paved or severely deteriorated roads (15–20%), and base repairs (5–10%) (World Bank, 2010).

Municipal maintenance contracts for local roads are typically input-based, meaning contractors are compensated based on the quantity of work or materials used. While this approach provides flexibility, it places most of the financial risk and administrative burden on contracting agencies. Each contract includes a detailed bill of quantities covering 109 distinct activities, and monthly workplans must be developed and evaluated. Given the limited staffing and capacity of local inspectorates, contract supervision and quality assurance remain significant challenges (World Bank, 2010). Moreover, maintenance strategies often favour reactive repair of degraded roads, while recently rehabilitated roads—despite being in good condition—are neglected under the rationale that maintenance funds should target problem areas. This short-term logic risks accelerating the deterioration of otherwise sound infrastructure, ultimately raising overall maintenance costs and leading to a gradual decline in average road conditions across the network (World Bank, 2010).

LIFECYCLE IMPLICATIONS OF UNDERFUNDING MAINTENANCE

Georgia's bias toward new infrastructure investment over maintenance poses significant lifecycle cost risks. As discussed earlier with Paterson's model (1987), the total present value of road costs is minimized when maintenance is performed at optimal intervals to prevent severe deterioration (Paterson, 1987) (see figure 6). In Georgia, however, maintenance has been persistently underfunded relative to new construction. Only about one-quarter of the road budget is allocated to routine maintenance and periodic rehabilitation – roughly 0.6% of GDP – while nearly 60% goes to new highway projects. Routine maintenance funding has remained around 0.1% of GDP for a decade. This imbalance means many road assets may deteriorate to poor condition before intervention, undermining their intended lifespan. Indeed, without increased upkeep, new highways built today could require premature rehabilitation just a few years later, negating the development benefits of those investments.

Figure 6. *Total of Maintenance Cost*



Source: Douglas, C (2017)

Insufficient maintenance leads to cost inefficiencies across the asset lifecycle. Road pavements follow a deterioration curve: without timely upkeep, pavement roughness worsens at an accelerating rate, causing sharply rising user costs (vehicle wear, extra fuel, travel delays) and eventually requiring extensive – and expensive – rehabilitation. Deferring routine repairs may save money in the very short term, but each GEL "saved" by skimping on maintenance can impose several GEL of costs in the future through higher rehabilitation bills or losses from poor transport quality.

International evidence echoes this pattern. For example, a U.S. study found that every $1 of road maintenance deferred can incur over $4 in future repair costs, and the World Bank estimated that $12 billion of timely road maintenance in Africa during the 1980s would have averted $45 billion in reconstruction costs the following decade (IMF, 2018). Neglecting maintenance also drives up indirect costs: vehicle operating costs can increase dramatically on poorly maintained roads, and safety risks grow as infrastructure deteriorates (IMF, 2018). In short, under-funding routine and periodic maintenance is a false economy – it trades modest upfront savings for much larger costs down the line, raising the total cost of infrastructure ownership. Georgia's own spending pattern – heavily weighted to new builds and reactive fixes – thus risks higher lifecycle expenditures and diminishing returns on investment, as roads deteriorate faster than they can be repaired.

In addition to increasing overall maintenance spending, it is crucial to prioritize the upkeep of roads that are still in good or fair condition (this section is particularly important for international and secondary roads, where a substantial share of the network remains in good or fair condition, yet the allocated maintenance budget remains relatively limited). Empirical evidence from Georgia's road network indicates that preventive maintenance at this stage yields the highest economic returns, helping to avoid costly deterioration and extend asset life efficiently. An HDM-IV simulation from a 2010 World Bank study illustrates that for a typical local paved road starting in good condition (International Roughness Index ≈3, AADT ~500), implementing regular routine maintenance dramatically lowers life-cycle costs (World Bank, 2010). Over a 20-year span, total transport costs (agency + user costs) drop from about $1,008,600 per km with a "do-nothing until rebuild" approach to roughly $960,700 per km with timely maintenance – a net present saving of ~$47,900 per km (World Bank, 2010). These savings are split almost evenly between reduced future rehabilitation expenses and lower road user costs (fuel, vehicle wear, travel time) due to smoother pavement. In cost-benefit terms, each $1 spent on routine upkeep of a road in good condition can avert about $8 in overall costs, thanks to both deferred major repairs and user cost reductions. By contrast, adding routine maintenance an expensive asphalt overlay mid-way (when the road is in fair condition IRI=5.5) yields only marginal extra benefit – total costs fall only another ~3% (to $959,300 per km) – because maintenance expenditures quadruple with the overlay. The marginal benefit-cost ratio drops to around 2.6:1 in that enhanced scenario (the benefits are purely the result of lower user cost), indicating diminishing returns (World Bank, 2010). Thus, basic routine maintenance of good roads offers the highest payoff, whereas more intensive interventions (overlays or late reconstruction) deliver smaller incremental gains.

The return on maintenance investment plummets once a road reaches poor condition (This section is particularly important for local roads, where the share of poor-quality infrastructure is especially high, rehabilitation progresses slowly, and maintenance spending remains low— with some municipalities allocating virtually no resources to road upkeep). HDM-IV simulations for a deteriorated asphalt road (initial IRI ~8) show that simply patching potholes on a very rough road without early rehabilitation not only fails to substantially improve ride quality, but can increase total costs by deferring the inevitable reconstruction. In one scenario, routine patching delayed the rebuild by 7 years (from 2020 to 2027) but kept the pavement in poor shape, so vehicle operating costs remained high; as a result, the present value of total costs was actually higher with routine maintenance than with none at all. Every extra dollar spent on patching such a road had negative returns (NPV ≈ –$66,000 per km) because the prolonged roughness imposed steep costs on users (World Bank, 2010). The optimal strategy in this case was to combine routine maintenance with a timely reconstruction (or overlay) at a lower roughness threshold – for example, rebuilding at IRI 10 instead of 16 yielded the lowest total cost. This combined approach produced a modest net gain (benefit-cost ratio ~1.5) by significantly cutting user costs in the later years (World Bank, 2010). The implication is that once pavements become badly degraded, only substantial capital repair (overlay or full rehabilitation) can reset the cost curve; routine maintenance alone offers brief respite but no lasting economic benefit in such cases. Put simply, "fix-it-later" is far costlier than "fix-it-early."

These efficiency dynamics vary across Georgia's road network categories and inform critical policy choices. Georgia's international highways (which carry heavy traffic) are relatively well-maintained – about 80% are in good condition – whereas only 5% of local roads are good and a staggering 75% of the local network is classified as *very poor* (World Bank, 2010). This disparity reflects past funding biases: major roads received resources for timely upkeep, while local roads were largely neglected post-independence. Crucially, the highest marginal returns on maintenance are achieved by preserving the roads that are already in good (or fair) condition, regardless of category. Even roads in fair condition offer strong returns to preventive repairs (by sealing cracks and potholes before they undermine the base), albeit slightly lower than for pristine roads due to higher repair costs. Therefore, after securing all good-condition sections, it is still economically efficient to maintain fair-condition roads as a second priority – their upkeep yields far greater benefit per dollar than funneling resources into severely dilapidated segments. However, current policy and public pressure often push the opposite approach. Municipalities tend to pour scarce funds into visibly poor roads in response to community complaints about bad access, while recently rehabilitated or decent roads receive little to no maintenance. This "worst-first" tendency may be politically understandable, but it carries heavy long-term costs. As the World Bank study warns, it creates a vicious cycle: roads in poor condition absorb most of the budget for only short-lived improvements, while good roads are left untended and deteriorate prematurely, eventually requiring costly repairs themselves. The outcome is a perpetually underperforming network and an excessive burden on limited maintenance funds, which are essentially spent inefficiently to chase ever-worsening conditions (World Bank, 2010).

INTERNATIONAL COMPARISONS AND BEST PRACTICES

A growing body of international evidence highlights the strategic importance of preventive and routine maintenance as a cost-effective alternative to rehabilitation and reconstruction of road infrastructure. While capital investments often dominate political and public attention—largely because they are classified as fixed capital formation and look favourable in public accounting systems—maintenance spending is treated as current expenditure under international standards such as the Government Finance Statistics Manual (IMF, 2014). This classification disincentivizes governments from allocating sufficient resources to maintenance, as increased spending in this area may appear to reduce government savings. In this context, many countries have struggled to strike the right balance between expanding infrastructure and sustaining its quality over time.

Despite this global challenge, several countries have implemented notable practices that provide valuable lessons for Georgia. Estonia has developed a relatively advanced public investment management framework that emphasizes lifecycle costing and performance-based contracting. The country maintains a comprehensive asset register and integrates road maintenance needs into medium-term budget frameworks, helping ensure that infrastructure assets are managed proactively rather than reactively. Although some institutional fragmentation persists, Estonia's systematic approach to road asset management contributes to more timely and cost-effective maintenance interventions (IMF, 2019). Poland has introduced mechanisms to secure predictable maintenance funding, most notably through the National Road Fund, which is financed by fuel charges and tolls. This fund supports both capital investment and maintenance and enables forward-looking planning. Road condition data are systematically collected and used to justify budget allocations, helping to maintain a balance between building new roads and preserving existing ones. Furthermore, technical assessments and cost-benefit analyses are embedded in investment planning, reinforcing the long-term cost-effectiveness of maintenance over reconstruction (IMF, 2019a).

Mexico has embedded maintenance obligations in its legal and regulatory frameworks. Multi-year maintenance budgets are required alongside capital investment plans, and maintenance costs are explicitly considered in the lifecycle assessment of infrastructure projects. Dedicated maintenance funds are also established, including for public-private partnerships (PPPs), ensuring that financial resources are reserved for asset upkeep. While implementation challenges remain—especially in terms of regional equity and execution capacity—the legal requirement to integrate maintenance into infrastructure management has yielded important benefits (IMF, 2019b).

Another instructive model comes from Chile, which has been a pioneer in performance-based maintenance contracting for roads. Through its National Infrastructure Fund and related programs, Chile uses long-term maintenance contracts that include explicit performance indicators – for example, requirements that road roughness (IRI) or pavement condition remain below a certain threshold on contracted sections. Contractors are paid not just for inputs but for outcomes, with penalties for non-compliance if road quality targets are not met (Mansilla & Vassallo, 2020). A robust government inspection regime underpins these contracts to ensure standards are maintained. This performance-based approach creates clear accountability and incentives for timely maintenance, as the private operators' profits depend on meeting maintenance outcomes. The Chilean model has influenced public-private partnership (PPP) maintenance frameworks across Latin America and offers a mechanism to depoliticize and guarantee maintenance activities. For Georgia, adopting elements of performance-based maintenance (even within traditional public works contracts) could help ensure that once roads are built, they are kept in good condition via enforceable standards, rather than waiting for periodic government-driven rehabilitation (Mansilla & Vassallo, 2020).

In comparison, Georgia has made significant progress in road rehabilitation, but institutional and budgetary shortcomings continue to hamper the sustainability of these achievements. According to the World Bank, Georgia's Public Investment Management Assessment (PIMA) revealed that maintenance is generally underfunded and poorly integrated into the investment cycle. Budget allocations disproportionately focus on rehabilitating roads in poor condition, while roads in good condition are often neglected. This leads to a vicious cycle in which previously rehabilitated assets deteriorate prematurely due to the lack of preventive maintenance, ultimately requiring costlier interventions in the future (IMF, 2018). These international cases underscore a key insight: investing in routine maintenance when roads are still in good or fair condition offers significantly higher returns than investing in reactive maintenance or full-scale rehabilitation once roads deteriorate. Performance-based contracting, dedicated maintenance funds linked to road use (such as fuel levies), and medium-term planning frameworks emerge as critical enablers of more effective road maintenance systems. Embedding maintenance into infrastructure appraisals and budget frameworks ensures that it is no longer treated as a discretionary expense but as a vital component of sustainable infrastructure policy.

Across these examples – Estonia, Chile, Poland (and others such as Mexico) – certain common principles emerge. High-performing road infrastructure systems establish clear expenditure classifications, enforce maintenance through dedicated funding or contracts, and build robust data-driven decision frameworks. They institutionalize the idea that maintenance is not discretionary but rather a fixed cost of asset ownership, to be planned for just as capital investments are. In Estonia, this meant changing budgeting rules; in Chile, changing contract incentives; in Poland, changing the planning toolkit. For Georgia, closing the maintenance gap will likely require a combination of all these approaches. As noted, aligning Georgia's practices with international benchmarks would involve improving asset data, revising budget coding, and strengthening institutional accountability for maintenance outcomes. In practical terms, reforms could include introducing performance-based maintenance contracts on heavily trafficked routes, carving out a protected maintenance fund or multi-year appropriation, and upgrading the road asset management database to track pavement conditions in real time. By learning from these international experiences, Georgia can move toward a more lifecycle-balanced infrastructure strategy – one that protects and maximizes the value of existing road assets while still allowing for strategic expansion.

CONCLUSION

Georgia's road infrastructure story, as examined in this paper, highlights that the country's foremost challenge is not a lack of new roads, but rather the upkeep of those already built. Decades of heavy investment in new highways and local roads have not been matched by a commensurate focus on maintenance, leading to visible quality issues despite high spending. Only a small fraction of local roads are currently in good condition, and even recently rehabilitated segments are deteriorating faster than expected due to insufficient routine maintenance. This gap between expansion and upkeep has created a vicious cycle: limited maintenance funds get thinly spread to address the most deteriorated roads, which in turn forces neglect of roads still in fair condition – hastening their decline and perpetuating the cycle. The analysis makes clear that breaking out of this *"build-neglect-rebuild"* pattern will require a fundamental reorientation of Georgia's road policy, essentially adopting a "maintenance-first" mindset going forward.

Looking ahead, Georgia has a significant opportunity to leverage international best practices and leapfrog towards more sustainable infrastructure management. The experiences of peer countries make one thing clear: nations that excel in infrastructure outcomes balance ambitious new investments with diligent maintenance, supported by strong institutions and planning frameworks. This lesson is highly relevant for Georgia. By decisively embedding maintenance into its fiscal and infrastructure planning frameworks – for instance, adopting formal maintenance planning standards, lifecycle cost analysis, and dedicated funding mechanisms – Georgia can greatly enhance the longevity and quality of its roads. Without prescribing one-size-fits-all solutions, the analysis signals a strategic direction for policymakers: prioritize maintenance as a cornerstone of road infrastructure policy. In essence, the findings encourage Georgia to institutionalize a policy ethos of *"maintain to enable, rehabilitate when needed, and only build anew when necessary,"* shifting the national infrastructure paradigm toward proactive asset care. Embracing this forward-looking, maintenance-first approach – and treating maintenance expenditure as an investment in the country's future – will align Georgia's practices with international norms and yield substantial economic and social returns in the long run. In conclusion, a sustained commitment to road maintenance is not merely a technical necessity but a strategic imperative for Georgia's development, ensuring that the roads built today will continue to support growth and connectivity well into the future.

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