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Infrastructure for Access to Basic Services in Amazonia[1]

Eduardo Cavallo and Carlos R. León-Gómez

Abstract

The Amazon region faces challenges in achieving effective access to infrastructure services. While investments have been made to expand transport, electricity, water and sanitation, and digital connectivity infrastructure, progress remains uneven. This report documents the state of infrastructure in Amazonia, the environmental implications of delivering infrastructure services in the region, and the governance challenges. The report also presents decentralized and context-based solutions like solar mini-grids, electrified river transport, and water cistern programs, that offer cost-effective, resilient, and environmentally sustainable solutions for the region. Drawing on case studies, academic research, and other initiatives the report argues that improving institutional capacity, strengthening cross-border coordination, and promoting innovative, context-specific solutions are essential to increasing access to infrastructure services in Amazonia.

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[1] This is an extended version of *Chapter 10. The Path To Better Infrastructure in Amazonia* in publication in Galindo, Giles Alvarez, & Rocha (Eds.). (2025). Amazonia: A Journey Toward Prosperity & Resilience. Inter-American Development Bank.

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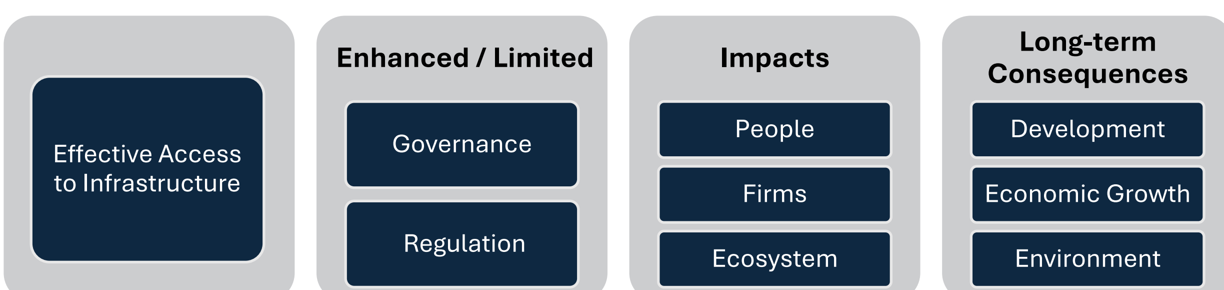
Introduction

Effective access to infrastructure can help reduce poverty, boost economic growth, and protect the environment. For that to happen, however, infrastructure assets must not only be available to the population. They also must have a certain level of quality and affordability (Straub, Serebrisky, Bagnoli, & Rojas, 2025). In recent decades, governments in the Amazonia region have committed significant resources to improving effective access to transport, electricity, water and sanitation, and telecommunications services. Yet there is heterogeneity in the accomplishment of those goals. What is true for all of Amazonia is that the access and quality of infrastructure services lag behind those of their respective countries as a whole (Bandura et al., 2020a), contributing to poverty.

When increasing effective access to infrastructure, it is essential to consider the key actors involved and the long-term consequences of each project. As a first step, infrastructure development and service provision are shaped by the regulation in place, and the governance practices under which they are implemented. Public authorities in charge of these duties can either enhance or constrain infrastructure outcomes depending on their institutional strength, coherence, and enforceability. Strong governance and sound regulation tend to promote infrastructure projects that maximize benefits for people and firms, while weak institutions and poor enforcement can create incentives that lead to environmental degradation or inefficient resource use.

The impacts of infrastructure decisions are felt across three dimensions: people's lives, firm productivity, and the surrounding ecosystems (see Figure 1). Governments face the challenge of expanding infrastructure access in a way that fosters inclusive development and economic growth. At the same time, they must explore solutions that minimize environmental degradation. This document deals with the decision-making and the trade-offs in enhancing infrastructure provision in Amazonia.

Figure 1. Conceptual framework on factors that contribute to the impact of infrastructure on long-term consequences



Source: Own elaboration

Developing and maintaining infrastructure in Amazonia presents specific challenges. The region's scale and interconnectedness require coordinated infrastructure planning, because interventions in one part can generate cross-border impacts (e.g. in areas such as river flow management). The region also faces challenges stemming from its vulnerability to climate change and extreme weather events. These challenges are particularly acute for populations already vulnerable due to limited or non-existent infrastructure. In this context, building resilient infrastructure is essential for achieving long-term development and economic growth in the region (see Bagnoli and Cavallo, 2025).

There are also differences across countries in the extent of their Amazonia territory and the size and characteristics of the population living there. For instance, in Brazil, Amazonia represents 62% of the country's territory and hosts a population of 29 million people (almost 15% of the country's population), more than 2.6% of which is of Indigenous origin. In Ecuador, by contrast, Amazonia represents only 1.6% of national territory and is inhabited by almost 1 million people (5% of the country's population) of which almost 25% is of Indigenous origin (RAISG, 2020). Based on this heterogeneity, interventions must be designed to support access to diverse populations, particularly due to access to basic services has been historically lower amongst minority groups.

The coexistence of urban and rural territories adds to the complexity of developing infrastructure for the region[2]. Manaus (2 million inhabitants) and Belem (1.2 million) in Brazil, Iquitos (0.5 million) and Pucallpa (0.3 million) in Peru, and Florencia (0.2 million) in Colombia, are densely populated and can benefit from economies of scale in providing *traditional infrastructure* (e.g. through the national electricity and broadband grids, water and sanitation pipelines, and official road networks). However, many municipalities in Amazonia are sparsely populated[3] and dispersed, with some estimates suggesting that the average distance between them is as high as 1,000 kilometers[4], underscoring the need for decentralized, or context-based solutions, to improve access.

The region requires the combination of traditional infrastructure to provide basic services in urban areas, and decentralized solutions to accommodate the needs of rural or sparsely populated areas. Those realities demand careful planning to prevent harm to Amazonia's

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[2] The Amazon region is experiencing rapid urbanization, with the urban population having risen from about 30% in 1960 to over 70% in the 2020s. This transition has been driven by multiple factors, such as better job opportunities, agrarian transformation, and the greater provision of public services in urban environments versus rural ones (Uribe, Lanfranco, & Martin, 2023).

[3] The urban population of Brazil's Legal Amazonia today stands at around 12 million people, with few large cities (greater than 500,000 inhabitants) and dozens of small and medium-sized cities, with populations ranging from 20,000 to 250,000. See: https://www.fao.org/4/j5416e/j5416e05.htm

[4] See here for more information.

ecosystems, the disruption of the livelihoods and rights of Indigenous and local communities, and prohibitively expensive solutions.

This document emphasizes the challenges and opportunities associated with improving access to infrastructure in the region. The next section reviews the state of infrastructure in Amazonia. Section 2 addresses the environmental and governance challenges. Section 3 explores decentralized and context-based infrastructure solutions and discusses alternatives for addressing governance challenges. Section 4 provides concluding remarks.

1. The State of Infrastructure in Amazonia

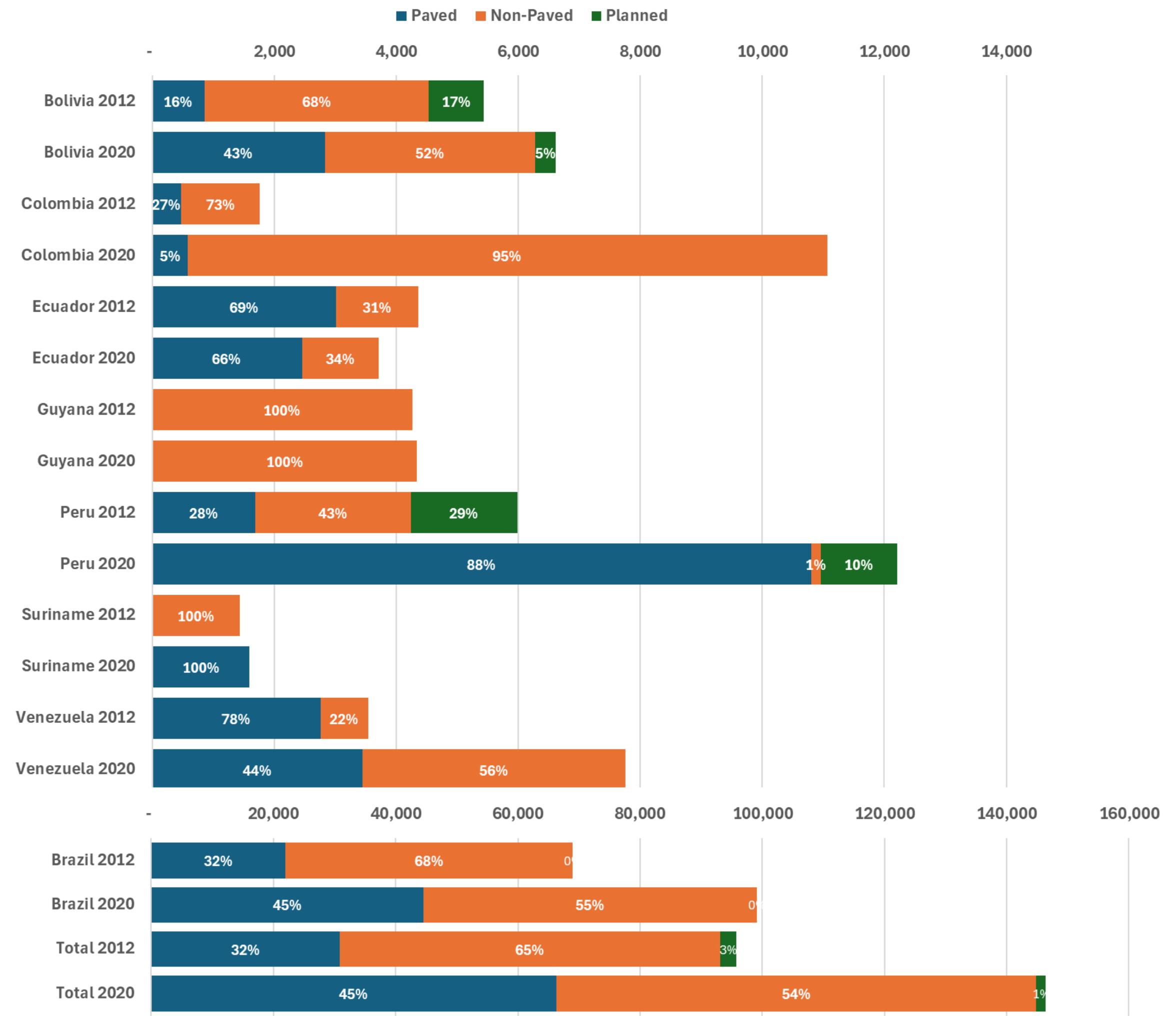
Measures of *effective access* to infrastructure are not readily available for the region. The scarce and heterogeneously distributed information available refers to physical access to infrastructure, like roads, electricity, and water and sanitation, regardless of their quality or affordability.

Amazonia's road network expanded by approximately 55% within the last two decades, reaching 145,000 kilometers according to the latest available estimates[5]. The share of paved roads increased from 32% to 45% (see Figure 2). The growth in the road network was led by Brazil with almost 30,200 km of new roads, followed by Colombia (9,300 km), Peru (6,200 km), Venezuela (4,200 km) and Bolivia (1,200 km). Paved roads represent a quality upgrade within the primary road network. But the improvements differed across countries. For instance, while Brazil prioritized the development of paved roads, accounting for over 75% of the increase in its network, the expansion of the road network in Colombia was driven by unpaved roads, accounting for 99% of its road expansion.

The enlargement of paved road networks across certain Amazonia countries stems from two main processes: the upgrading of existing unpaved roads and the implementation of planned road infrastructure projects to varying degrees. For example, in Surinamese Amazon, the road network documented in the 2012 report consisted entirely of unpaved roads stretching across around 1,400 km. By 2020, the new report showed that the entire network had been upgraded to paved roads, with additional new paved segments incorporated into it for a total of 1,500 km. In Bolivia and Peru, approximately 60% and 45% respectively of the increase in paved roads in the 2020 report was due to the combined effect of the reduction in unpaved roads and the implementation of planned infrastructure documented in the 2012 report.

[5] These figures refer to reported data by the Amazon Network of Georeferenced Socio-Environmental Information (RAISG) which consisted in georeferenced primary roads at the national level, both paved and unpaved, as data availability on secondary and tertiary roads differs across Amazonian countries (RAISG, 2012). The reported data corresponds to the most recent data available at the moment of the report, and it differs across countries because the frequency of data collection varies from one country to another. See RAISG (2012, 2020) for detailed information.

Figure 2. Road length in Amazonia (km)



Source: Own elaboration with data from RAISG (2012, 2020)
Note: The years shown correspond to the available data nearest RAISG report publication's date.

Although all types of roads in Amazonia have economic, environmental, and social implications, the nature and extent of these impacts vary according to whether they are official or unofficial (see Table 1). Official roads, intended for national or regional connectivity, are typically constructed as part of broader strategies for social and economic integration and may indirectly drive change along highway corridors. By contrast, unofficial roads are often developed by private actors seeking direct access to natural resources or ways to engage in illegal activities. Nonetheless, in many cases, the construction or paving of official roads serves as a catalyst for the expansion of unofficial road networks (Perz, 2014). There is no consensus on the total extent and nature of the road network (Savoldi Jr., 2022), but studies estimate that official roads represent between 15-28% of the network[6] and that around three quarters of it have been unofficially built.

Table 1. Road's Classification

	Official	Unofficial
Paved Roads	Major highways and corridors planned by the state	Rare, but may emerge over time from informal upgrades
Unpaved Roads	Recognized feeder roads, rural access routes	Logging tracks, mining access, new settlers' roads.

Source: Own classification

Despite the expansion of roads in recent decades, connectivity remains limited for many parts of Amazonia. This fragmentation restricts people's ability to access essential public services, such as education and healthcare, as well as better job opportunities, ultimately affecting their quality of life. Giles et al. (2025) estimate that approximately 7.1 million people live more than 45 minutes away from a primary road and 4.7 million are similarly distant from a secondary road[7], affecting access to public services and the labor market for working age people as well as access to education for school-aged children.

Water transportation could improve freight and passenger mobility. Approximately 51% of the Amazonia has a direct connection to waterways. But countries in the region do not fully take advantage of it. The use of waterways is currently constrained by limited investment in infrastructure, insufficient maintenance, and inadequate climate resilience. In northern Brazil, inland water transport accounts for 90% of cargo movement, and in the state of Amazonas, an estimated 30% of urban communities are accessible only by boat (Tornaghi, 2021). This illustrates the importance of water transport infrastructure for cargo shipment and for improving the connectivity of remote populations. Nonetheless, in the Brazilian Amazonia, only 6,500 kilometers of more than 20,000 kilometers of navigable rivers are used for regular commercial shipping (Ivarsson & Sekerinska, 2025) and remote areas often lack adequate port facilities. Instead, they must rely on rudimentary structures such as small piers or sloped riverbanks for the loading and unloading of passengers and goods (Bentes & Cury, 2017).

Infrastructure resilience is crucial for water transport. Episodes of climate variability, particularly the severe droughts of 2005, 2010, 2016, and 2023, have disrupted inland navigation in Brazil. They have left communities isolated, limiting their access to food, fuel,

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[6] Studies such as Barber et al. (2014), have documented a total of 264,000 km of all types of roads in the Brazilian Amazonia as of 2007, including 190,500 km of unofficial roads. This means that approximately 72% of the road network was unofficial, while only 28% was official. Meanwhile, Bothelo et al. (2022) documented a road network totaling 534,000 km, composed by 80,000 km of official roads and 454,000 km of unofficial roads.

[7] These calculations likely underestimate measures of road quality, which if considered, would expand the gap considerably.

medicine and critical public services, like healthcare and education (Santos et al., 2024). In the Colombian Amazonia, where approximately 7,000 kilometers of navigable waterways and 99 port facilities exist, inland water transport handles about 30% of national cargo and 15% of passenger transport. But the quality of service remains inconsistent due to deficient port infrastructure and frequent flooding (BID, 2023).

In terms of electricity, as of 2020, there were more than 350 dams operating in Amazonia, contributing an average of 55% of total installed capacity in Brazil, Bolivia, Colombia, Ecuador and Peru (Viscidi & Phillips, 2021). Hundreds more are planned. These include around 450 small and big hydroelectric plants in Brazil's Amazonia and others in Peru and Bolivia as those nations seek to boost the percentage of hydropower in their energy mix (see Table 2). However, at least 10% of the plants are operating or planned in protected natural areas, and over 5% are operating or planned in indigenous territories (RAISG, 2020),[8] leading to potential disruptions in the ecosystems and the displacement of local ethnic populations.

While Amazonia has an abundance of dam-derived energy, not all dams in the region serve the interests of the local communities. Six large dams slated for construction in Peru through a 2010 agreement between the Peruvian and Brazilian governments, for example, were intended to export most of their electricity to Brazil (Fearnside, 2020). The paradox is that a lack of connectivity structures has led to a lack of electricity coverage for large sections of the population. In rural parts of Amazonia, for example, 4.3 million people (8.9% of the Amazonia population), including 1.3 million school-age children, do not have reliable access to electricity[9]. Meanwhile, 6.3 million people, and 1.6 million school-age children could benefit from better electricity access (Giles, Avila, & Vargas, 2025)[10].

[8] According to RAISG (2020), the disaggregation between protected natural areas (PNAs) and Indigenous territories (ITs) does not consider the headwaters of Andean basins or the south-eastern part of the Brazilian Amazonia.

[9] This figure is calculated by summing up all the populations of the administrative districts where the share of households with access to electricity is below 96.4%. As such, it should be considered an upper bound of the potential beneficiary population, regardless of whether electricity access in a given district is very low or just slightly below the threshold.

[10] Since urban areas have better access to electricity, we believe that this number should be considered with caution and as an upper bound limit.

Table 2. HYDROELECTRIC PLANTS IN AMAZONIA Current and planned hydroelectric plants reported in 2020					
	Current		Planned		Total
Country	Small	Big	Small	Big	
Brazil	137	44	340	107	628
Peru	61	15	4	9	89
Ecuador	28	34			62
Bolivia	1	13	1	14	29
Venezuela	10	4	5	2	21
Colombia	1				1
French Guyana		1			1
Guyana				1	1
Suriname		1			1
Total	238	112	350	133	833

* Notes: Small (less than 30 MW); Big (more than 30 MW). The year reported corresponds to the available information nearest the publication's date. Source: RAISG (2020)

Infrastructure provision is also characterized by considerable geographic heterogeneity in the quantity and quality of services. Some municipalities, particularly those located near major urban centers, boast infrastructure that ranks well by national standards. Still, there is evidence of underinvestment across the region. In the case of Water and Sanitation, by some estimates, 45% of the territory and up to 11.5 million people that live in these administrative areas have an average household access to sanitation of under 9%.[11] Meanwhile, average household drinking water access by administrative area is estimated to be below 43% in almost 30% of the territory,[12] impacting 11.2 million people (Giles, Avila, & Vargas, 2025). Indeed, while hardly uniform, services in the departments of Amazonia overall tend to lag the rest of their respective countries. Access to sanitation and drinking water in Colombia's Amazonia, for example, is at a rate 30% below the national average, while in Peru´s Amazonia that stands at 20% below the national average (Bandura et al., 2020, pp. 36).

Digital connectivity is crucial for Amazonia's socioeconomic development as it enables access to public services for remote populations, such as distance education, telehealth services, communication, and political participation. Users with high-speed connectivity are around a third more likely to engage in essential activities online, like accessing healthcare, taking a class, looking for a job, or participating in the digital economy (Jorge &

[11] The benchmark of 9% was selected based on WHO and UNICEF estimates. For more information, see Giles Alvarez et al. (2025).

[12] 695 out of 2,503 administrative areas observed rates of household drinking water below 43%. The benchmark of 9% was selected based on WHO and UNICEF estimates. For more information, see Giles Alvarez et al. (2025).

Makwakwa, 2024). However, only 8% of the Amazonia region has high-speed internet that corresponds with its population density,[13] and even in areas with high population density, there are often inadequate levels of connectivity.

A problem in areas of low population density is that private investment is less likely to see adequate financial returns. In such cases, public support can play a crucial role. At present, only low-speed internet is available in 38% of the Amazonia region with low population density. This is insufficient to effectively support the delivery of public services and fully allow the population to access education or health services (Ivarsson & Sekerinska, 2025). In the Brazilian Amazonia alone, more than six million people, as well as 14,000 schools and 2,500 health facilities, are not connected to the internet (Alarcon, et al., 2022). This gap is exacerbated by the poor quality and inadequate resilience of existing networks, primarily a result of insufficient international connectivity and weak backbone links that interconnect networks. These deficiencies lead to limited capacity, low service quality, and excessive costs for both public and private users. Affordability is another major issue. About two million people (22% of the population) are unable to afford even a basic mobile broadband plan, and 6.1 million households (72% of the population) cannot pay for a fixed broadband connection. To bridge this digital divide spanning the states of Brazilian Amazonia, an estimated $3.5 billion investment in network infrastructure would be required[14].

Although granting digital connectivity is a step for increasing access to services in Amazonia, it should be accompanied by other types of investments. For instance, distance education using technology could reduce the need for physical access in remote regions if there were fast connections to the internet and access to digital devices. Giles et al. (2025) has documented that 80% of schools in rural Amazonia do not have digital devices, like portable tablets or computers, available for students. This highlights the importance of developing comprehensive policies that maximize the impact of infrastructure investment.

2 Infrastructure Challenges

2.1 Environmental Impact

Highways and roads play a major role in Amazonia, moving people and cargo within the region and connecting it to other regions in ways that facilitate access to public services, jobs, and trade. Hydropower facilities generate huge quantities of renewable energy, reduce

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[13] According to Ivarsson & Sekerinska (2025), this comparison is performed using two indexes, the Google's building footprint data (as a proxy for population density and development) and Ookla's internet speed metrics. They classify each index in two categories, high and low. When both indexes match in the same category (e.g. high-high), it means that the level of correspondence between the indexes is shared, in other words, the speed level of the internet is adequate for the population density. Meanwhile, when the indexes differ (e.g., low-high), it means that one of the indexes is underdeveloped relative to the other; that is, the installed infrastructure is insufficient to bridge the needs.

[14] See Crowdsourcing for Digital Connectivity in Brazil (C2DB): https://c2db-idb-gis.hub.arcgis.com/

the need to import and spend money on fossil fuels and, like roads, are enablers of economic and social activities, as well as drivers of economic growth. Yet neither the building of roads and highways or the construction of dams is immune to challenges, specifically those related to deforestation and ecosystem degradation.

Amazonia has lost 15% of its original forest since 1970. Brazil accounts for the most significant deforestation among the eight countries, having lost 21% of its original forest cover. Bolivia, Colombia, Ecuador, and Peru have lost approximately 10% each. Meanwhile, the northern Amazon region, spanning Venezuela, Suriname, and Guyana, remains largely untouched. Although the main drivers of deforestation are often agriculture-related (e.g., palm oil, soy and cocoa), or connected to cattle ranching, timber and mining activities (Ferreira, 2023), estimates have documented that 95% of the deforestation in Brazil's Amazonia occurs within 5 km of a road or 1 km of a navigable river (Barber et al., 2014). There is, in other words, a high association between transportation infrastructure and deforestation, even though transport infrastructure's direct contribution to the destructive phenomenon is comparatively small (e.g. building a highway).

Unofficial roads are a significant driver of deforestation, as they often enable illegal activities such as unauthorized logging, unregulated cattle grazing, and other forms of informal resource extraction. These unofficial roads are typically built to access remote areas rich in natural resources. But once those resources are depleted, the groups involved in their exploitation typically abandon the area in search of another place to carry on with the same activities elsewhere. This cyclical pattern of exploitation and expansion not only accelerates forest loss but also complicates enforcement efforts and long-term land use planning.

Unofficial roads also disrupt local communities and undermine the integrity of protected natural areas and indigenous territories. In the Colombian Amazonia, approximately 2,336 kilometers of these roads cross indigenous lands, while 7,975 kilometers intersect protected areas, contributing to deforestation, both directly and indirectly (Bandura et al., 2020).

Electricity from hydroelectric plants on the rivers of Amazonia is abundant and cheap[15], accounting for more than half the installed capacity in Brazil, Bolivia, Colombia, Ecuador and Peru. In recent years, however, growing concerns have emerged regarding not only the efficiency and sustainability of large dams in Amazonia, but also their significant environmental impacts. The problems of efficiency and sustainability are illustrated by the severe droughts and historically low river levels observed across the basin in 2024, which sharply reduced electricity generation from hydropower plants and reduced fluvial

[15] There is a debate about the cost of this type of infrastructure. In the global context, Ansar et al. (2014) documented hundreds of hydroelectric projects that were not financially profitable.

transportation, as well. The environmental elements refer to the substantial and often unaccounted environmental costs of this type of infrastructure. Fearnside (2016) documents several key impacts of hydroelectric plants in the Brazilian Amazonia: (1) flooding-related losses, including deforestation in areas inundated by dam reservoirs and in surrounding regions due to their greater accessibility; (2) ecological disruption both upstream and downstream, where dams fragment river habitats and obstruct fish migration routes, resulting in biodiversity loss and greater extinction risk for endemic aquatic and bird species; and (3) degradation of critical ecosystem services such as natural water filtration, carbon storage, and flood regulation due to disrupted sediment flows and wetland decline. These losses highlight that although the physical infrastructure may be located in one country, the negative environmental impacts can extend into other countries. This transboundary dimension of hydropower underscores the need for coordinated, basin-wide governance and planning that balances national energy goals with the protection of the region's shared ecological integrity (Latrubesse et al., 2017).

2.2 Governance Deficits

Enhancing institutional quality increases the economic returns of infrastructure development (Zergawu, Walle, & Giménez-Gómez, 2020). Although countries have made significant progress in creating situations that support efficient, impactful, and sustainable projects with private participation, the overall lack of project preparation mechanisms remains a major obstacle to the development of quality projects (INFRASCOPE, 2024). This lack of governance quality is often linked to costly delays, rent-seeking, and even the failure of infrastructure megaprojects (Estache & Fay, 2010; Cavallo, Powell, & Serebrisky, 2020; Flyvbjerg, 2014).

In the Amazonia, a source of concern is the absence of coordination between national and subnational authorities, resulting in poorly aligned infrastructure plans that often remain incomplete. For example, in the early-2000s, South American countries embarked on an ambitious initiative to integrate highways, waterways, and hydroelectric dams through the Initiative for Integration of Regional Infrastructure (IIRSA). Yet, both that initiative and others have often been marred by poor planning, and the failure to consult with local communities or consider local governing capacity. Because of inadequate planning, major highways built by national governments often fail to connect to a well-developed network of secondary roads, which are more frequently the responsibility of underfunded local governments (Bandura, 2020). While key corridors, such as the Interoceanic Highway connecting Peru and Brazil have been successfully completed, many projects remain stalled at various stages of planning, approval, or construction.

Poor planning and weak regulatory oversight have created fertile ground for interest groups to dominate procurement processes and extract economic rents, severely damaging infrastructure development efforts. In some cases, bribery and corruption have prompted planners to bypass critical, high-quality feasibility studies and, in some instances, to procure materials at artificially inflated prices. Addressing these governance shortcomings, ensuring a more transparent and competitive bidding process, and engaging local communities through meaningful consultation at the earliest stages of project planning are critical steps toward achieving more sustainable and socially responsible infrastructure development in the region.

Enforcement and a clear definition of property rights is also crucial. In their absence, public and community lands are often taken over by ranchers, agricultural interests, and mining and oil companies. More than 54 million hectares of public land in Brazil is undesignated (i.e. almost as much land as in the state of Minas Gerais, Brazil's fourth largest state), and much of that is in Amazonia (Sparovek et al., 2019). Because of a lack of oversight bodies, resources and personnel to oversee the use of land, it frequently ends up being registered as private property, a form of land grab that authorities find difficult to prevent and that leads to an overlap between undesignated lands and areas registered under private and public tenure. The problem is not the lack of laws, but limited enforcement. The complexity of laws and regulations, coupled with fragmented land titling systems, exacerbates these issues. Such governance problems not only impede infrastructure projects but also threaten environmental conservation and the rights of Indigenous communities (Bandura & Murphy, 2020).

Although environmental protection regulations have improved in recent decades, enforcement capabilities remain underdeveloped and are often insufficient to prevent illegal activities such as unauthorized logging and mining. The establishment of protected areas has proven to be an effective tool for reducing deforestation, provided that adequate enforcement mechanisms are in place. But in Amazonia, their effectiveness varies depending on their proximity to infrastructure and accessibility. A study by Barber et al. (2014) find that protected areas near roads and rivers experienced substantially lower deforestation rates (10.9%) compared to unprotected areas with similar levels of accessibility (43.6%). These findings underscore the importance of combining legal designation with strong institutional capacity to ensure the long-term effectiveness of conservation policies.

Access to digital connectivity presents yet another challenge for Amazonia. The region's low population density and the long distances to well served cities raises the cost-of-service provision (Prado & Bauer, 2021). Many Amazonian municipalities are small,[16] and the investment and maintenance costs per subscriber in these areas, according to Alarcon et al. (2022) are approximately 30% higher than in larger municipalities, while annual revenues per subscriber are marginally lower (-0.44%). This cost–revenue imbalance discourages private investment and is especially related to the high costs associated with building high-capacity fiber-optic transmission networks. Public investment will be critical to expanding digital connectivity in the region. In the case of Brazil, 83% of the investments in digital infrastructure already rely on public funding to attract private capital and ensure long-term economic viability.

The internet service provider (ISP) market, meanwhile, lacks sufficient revenue to support expansion into underserved areas. In the Brazilian Amazonia, there is an estimated US$1 billion gap in financing needed to meet the investment demands of ISPs. The market is composed of hundreds of small ISPs with annual revenues between US$1 million and US$10 million, and thousands of even smaller providers below that threshold.[17] Small ISPs often serve market segments neglected by larger carriers. Their scale and fragmentation make it difficult and costly for financial institutions to conduct the due diligence necessary to extend credit, hindering the development of broadband infrastructure in remote communities. Improving regulations that promote innovation in this sector should be a priority for increasing access to digital services.

3. Enhancing Infrastructure

Developing infrastructure in Amazonia is challenging. Cities and rural areas of Amazonia are sparsely distributed, and bringing infrastructure services to small municipalities through traditional methods is costly from a financial and environmental perspective. In this context, traditional ways of extending the electricity or broadband grid, laying water and sanitation pipelines, or building road networks, can be technically and financially unfeasible for many localities. Infrastructure is also vulnerable to climate events such as droughts, wildfires, and flooding, which can damage critical assets, disrupt service delivery, and increase maintenance costs. These dual challenges highlight the need for innovative, resilient, and decentralized infrastructure solutions that minimize environmental impacts while enhancing the capacity of communities to withstand and adapt to extreme weather events.

[16] Municipalities with less than 30,000 inhabitants.

[17] For instance, data from the International Telecommunication Union show that Brazil has nearly 20,000 internet service providers (ISPs). This is by far the highest number not only among the countries that make up the Amazonia region (e.g., Colombia with 1,100 ISPs, Ecuador with 1,000, and others with fewer than 60) but also across Latin America and the Caribbean, where Argentina ranks a distant second with 4,100 ISPs. See https://datahub.itu.int/data/?e=ZAF&i=19174

According to Blackman et al. (2025), enhancing infrastructure resilience to extreme weather involves several key actions. First, stronger structures must be built to withstand extreme weather. Hallegatte et al. (2019) estimate that strengthening new infrastructure in low- and middle-income countries adds only 3–6% to capital costs in the power sector, 1–2% in water, and about 5% in transport, modest increases compared to the substantial benefits. Infrastructure must also be stopped from deteriorating through maintenance and retrofitting. Poor routine maintenance has raised replacement costs by at least 50% in transport and 60% in water infrastructure between 2015 and 2030 (Rozenberg & Fay, 2019). Infrastructure diversification, decentralization, and redundancy are also critical. These strategies can be supported by tools such as decision-making under deep uncertainty (DMDU) and blue spot analysis, which help prioritize solutions under extreme climate risks. Finally, ecosystem-based infrastructure and demand-side behavioral interventions should also be considered (see Bagnoli and Cavallo, 2025).

3.1 Decentralized and context-based Infrastructure

Increasing connectivity redundancy in transportation is a priority for Amazonia. Dense rainforests and seasonal flooding often render road and railway transport unusable for parts of the year, making waterborne transport essential. But navigable rivers can also become dry or impassable due to shifting hydrological patterns, underscoring the importance of better inter-modal transport planning (Fioravanti & Torres, 2025). While water transport offers a more sustainable and context-appropriate solution for the region, it is underutilized (see section 1.1). Improving connectivity could significantly increase its share of overall transportation. Moreover, unlike road transport, waterborne transport in Amazonia is typically a pooled service (shared by individuals or companies) whether provided by public or private operators. This characteristic makes it particularly suitable for policy interventions aimed at maximizing environmental and social benefits. For that reason, the public sector should actively promote it and encourage the adoption of electric mobility technologies within the fluvial transport sector (BID, 2023).

Several pilot initiatives are already demonstrating the feasibility and benefits of electrification in river transport systems in Amazonia. For example, in Ecuador, the Kara Solar project, has introduced solar-powered canoes with a capacity of up to 20 passengers. These solar-electric vessels have replaced traditional gasoline-powered boats and operate along approximately 60 miles of river routes, connecting nine Indigenous Achuar communities.[18] Meanwhile, in Brazil, a solar-powered vessel in the community of Santa Rosa, Pará, was developed through a collaboration between the Federal University of Pará

[18] For more information, see projects EC-T1577 (https://www.iadb.org/en/project/EC-T1577) and EC-G1016 (https://www.iadb.org/es/proyecto/EC-G1016)

and private sector partners, with support from the Ministry of Science, Technology and Innovation. Designed to transport students from the island where they lived to the municipal school on the mainland and featuring a capacity for 22 passengers, it is operated autonomously and powered entirely by photovoltaic solar energy.[19] In Peru, the IDB is providing technical assistance to improve fluvial transportation connectivity and access to basic services in Amazonian Riverine Population Centers (NPRAs). These examples illustrate how context-based transportation solutions can be implemented in Amazonia, and how they can contribute to greater redundancy, improve intermodal connectivity, and promote sustainable and resilient transportation services.

Similar principles apply to energy access. A few large urban centers are already connected to the national electricity grid, allowing for traditional grid expansion as the cities grow. However, this traditional electricity infrastructure, dependent on long-distance transmission lines and centralized grids, is a prohibitively expensive solution for many isolated small and medium-sized populations, especially those with difficult terrain access. Moreover, it is environmentally harmful and technically unfeasible, with a high vulnerability to climate disasters. On the other hand, PV solar technology is a more efficient and sustainable alternative. By providing decentralized, locally generated power, these systems offer a practical solution for delivering electricity to remote communities and small towns. The declining costs of solar panels and related technologies have made them technically viable and economically competitive, providing a complementary solution for accessing energy sources.

The IDB is supporting this line of action with different initiatives. For instance, the Amazon Clean Energy Accelerator seeks to achieve universal access to clean energy, the decarbonizing of electricity systems, clean cooking, and the expansion of emerging clean technologies and solutions in Amazonian regions. The Accelerator's portfolio includes renewable power generation, mini-grids, energy efficiency, digital grid infrastructure, and clean cooking solutions, with a strong emphasis on inclusion, innovation, and resilience. Additionally, a program known as the Bio-economy Empowerment in Suriname Indigenous Communities through Access to Water, Energy and Telecommunications addresses the severe isolation of Amazonian villages where electricity costs are considerable due to diesel reliance. The program finances the supply, installation, and commissioning of solar mini-grids, reliable water supply, and new distribution and access to telecommunications infrastructure. This program also supports the development and implementation of productive and sustainable use projects while strengthening the institutional capacity of the public sector to plan, design, and supervise rural electrification and water projects. It is

[19] See https://revistapesquisa.fapesp.br/barco-autonomo/

expected to directly benefit about 1,200 households, and numerous health clinics, schools, and businesses in Amazonia with a special focus on local farmers, small business owners, women, Indigenous populations, and Afro-descendants.

National programs for decentralized infrastructure have been implemented for improving infrastructure access in Amazonia. In 2020, Brazil's government launched the More Light for the Amazon (Mais Luz para a Amazônia) program to expand electricity access to remote areas of Amazonia through decentralized renewable energy systems. Consisting primarily of individual solar photovoltaic systems with battery storage, these systems provide a reliable and sustainable energy source for communities unconnected to the national grid. They also require minimal maintenance and are a more resilient and environmentally friendly alternative to extending the national grid through flood-prone and heavily forested regions.[20] There are currently about 82,000 families without access to public electricity services in the Brazilian Amazonia, and the initiative is expected to reach thousands more people living in remote areas .[21] Other initiatives have adopted self-contained microgrid systems to deliver reliable electricity to remote communities. For example, the Vila Limeira Solar Mini-Grid provides 100% solar-powered electricity to a small village of 90 residents deep in the Amazon.[22]

Water cisterns also offer an opportunity for bringing critical infrastructure services to remote populations. In 2003, the Brazilian government began implementing an innovative program of cisterns to ensure a readily available source of accessible and clean water for Amazonia. By 2017, the program had distributed nearly 880,000 of them, each holding about 16,000 liters, enough to see a family of five through a dry season lasting as long as eight months. The relatively low cost ($790 per unit) and fast construction (about two days) adds to the success of the program.[23] In particular, a study showed large welfare benefits examining 600,000 people over the 14 years of the program. For instance, it found a 23% increase in formal employment and an 8% boost in formal labor income as people, freed from the time-consuming hunt for drinking and cooking water, could now look for work at a greater distance from their homes and make the time commitments required for far-flung jobs. The

[20] See https://news.mongabay.com/2023/02/electricity-day-and-night-solar-power-is-changing-isolated-amazon-communities/

[21] See https://www.gihub.org/quality-infrastructure-database/case-studies/program-more-light-for-the-amazon/

[22] See https://www.mott.org/news/articles/from-diesel-to-solar-how-harnessing-solar-energy-is-transforming-and-empowering-an-amazonian-community/

[23] Before the introduction of cisterns, families depended on small lakes and reservoirs to obtain water. This posed challenges both in terms of time spent collecting water and the quality of the water consumed. A survey of cistern recipients found that only 5.6% of respondents spent less than 15 minutes per day fetching water before receiving the cistern, while 35% reported spending an hour or more. After receiving a cistern, 66.6% of respondents spent less than 15 minutes on this task, and only 0.2% still spent an hour or more (Barreto et al., 2023). Moreover, the cisterns significantly reduced the incidence of waterborne diseases and contributed to improved health outcomes (Sousa, Araujo, Sebastiao et al., 2025).

hospitalization of beneficiary adults dropped by about 10%, and ten years after the start of the program their reliance on conditional cash transfers had fallen by 12%, reflecting a reduction in poverty (Barreto et al., 2025). The IDB is also supporting water security through the Program for Improving Climate Resilience by Increasing Water Security in Amazonia. The program aims to enhance knowledge and access to information on water security, strengthen preparation for both extreme and gradual climate events, and catalyze investments in climate-resilient and low-carbon water supply, sanitation, and waste management technologies and infrastructure. It also seeks to foster an enabling environment for climate change planning and investment and establish mechanisms to ensure inclusivity and diversity across interventions in participating countries.

When it comes to extending the broadband network, extending it to remote and sparsely populated communities requires a strategic blend of public investment, targeted subsidies, and improved access to financing mechanisms. The lack of enabling, cross-border and in-land digital connectivity, explain the limited capacity, quality, and reliability of the internet in the region. Enhancing internet access and use in the region should thus rely on a combination of tailored solutions. In those cases where existing infrastructure corridors are available, for example, in areas where navigable waterways infrastructure already exists, deploying broadband infrastructure may offer a relatively non-invasive alternative, avoiding the need for deforestation. *Brazil's Norte Conectado* program provides a case study on this type of solution. It aims to install over 12,000 kilometers of sub-fluvial, fiber-optic cable along navigable waterways, connecting 59 municipalities and benefiting approximately 10 million people, while preserving an estimated 68 million trees by avoiding deforestation. Additionally, through the *Pará Mais Conectado* program, a $144 million initiative of the State of Pará co-financed by the IDB and the French Development Agency, a submarine fiber optic cable system is being built linking Pará with international connectivity hubs in Fortaleza, Brazil, and Cayenne, French Guiana. This will connect the sub-fluvial, optic-fiber cables of the *Norte Conectado* program to the world. The program also includes the development of a high-capacity backbone ring in the region, among other digital inclusion initiatives (connectivity in schools, riverside and Indigenous communities), ensuring scalable, resilient, and universal digital connectivity in Pará. With this approach, a considerable increase in quality and resilience is expected, as well as a reduction in the price of the broadband services in Pará, resulting in enhanced access and use of internet by its population. In parallel, satellite broadband provides a fast-to-deploy interim solution for reaching isolated communities in Amazonia. However, due to its capacity limitations and higher cost per Mbps, it is best suited for targeted applications that support sustainable economic activities, to connect extremely small and dispersed populations, or to serve seasonal communities that cannot be reached by fixed infrastructure.

3.2 Boosting Institutional Capacity and Coordination

A first step to improving infrastructure in Amazonia is establishing effective coordination mechanisms between national, subnational, and cross-border authorities to avoid fragmented planning of infrastructure. Countries should develop cross-jurisdictional infrastructure maps that consider both strategic corridors and secondary networks and involve municipal authorities early in the planning phase. Strengthening regional mechanisms, such as the Amazon Cooperation Treaty Organization, can promote information sharing, harmonize standards, and facilitate joint investment planning among Amazonia countries. These coordination efforts must go beyond governmental actors to include multilateral institutions like the examples of the Regional Program for South American connectivity (see Box 1) or the Alliance for Sustainable, Resilient, and Integrated Transport in the Amazon (see Box 2). Civil society organizations, ethnic and Indigenous groups, and academic communities must also be recognized as strategic stakeholders in both intergovernmental and cross-border governance, since their participation brings essential knowledge, enhances accountability, and increases the social legitimacy of infrastructure projects. Initiatives that improve planning processes and increase the likelihood of project success should be considered. For instance, a planning mechanism proposed by researchers from the Climate Policy Initiative and the Pontifical Catholic University of Rio de Janeiro recommends a new stage in the project's life cycle called the pre-viability analysis stage, which aims to reduce uncertainties and enable more detailed assessments early on. This would help to prevent low-quality projects from advancing and mitigate pressures driven by institutional inertia or political interests (CPI, 2020).

Box 1. South Connection: A Regional Program for South American Connectivity

The South Connection Regional Program (2025–2030), led by the IDB Group, is a flagship program endorsed by 11 South American nations to address persistent economic stagnation and regional fragmentation. With average growth of just 1.7% over the past decade, the Program aims to boost connectivity, competitiveness, and sustainable development through a coordinated, multi-sectoral approach. Its geographic scope includes the Amazonia Region, with a strong commitment to sustainable infrastructure, improved connectivity, and inclusive economic growth.

South Connection seeks to reverse current trends by substantially increasing investment—well above the historical 1.8% of GDP—and deepening integration into global value chains. It is built around three strategic priorities:

- **Infrastructure Development:** Cross-border transport, energy, and digital networks to eliminate bottlenecks and expand market access.
- **Trade Facilitation:** Streamlined logistics and regulatory processes to strengthen supply chains and reduce costs.
- **Institutional Strengthening:** Regulatory convergence and governance reforms to attract investment and enhance transparency.

The IDB Group will mobilize financing through sovereign and non-sovereign operations, public–private partnerships, and regional collaboration. Demand-driven projects will be prioritized based on rigorous technical, financial, and political analysis to ensure measurable impact and market relevance.

By integrating infrastructure, facilitating trade, and regulatory improvement, South Connection provides a platform for regional cooperation and transformation, repositioning South America as a competitive, resilient, and sustainable player in the global economy.

Box 2. Alliance for Sustainable, Resilient, and Integrated Transport in the Amazon

The Alliance for Sustainable, Resilient, and Integrated Transport in the Amazon is a joint initiative led by the IDB, the World Bank, federal and subnational governments, and international and local stakeholders from eight Amazonia countries. The initiative leverages climate financing and technical assistance to support initiatives and projects that transform transport infrastructure and services in the Amazonia region.

This alliance aims to bring together diverse stakeholders to transform transportation in Amazonia, through the development of transport infrastructure and services that enable economic activities, improve access to goods and services, and that are developed in harmony with the environmental regulations and principles. Deeply anchored in the IDB's Amazonia Forever Regional Program, its objectives are the following:

1. Improve connectivity and access to basic services in isolated communities across Amazonia territories, based on a model that prioritizes sustainability, resilience, and regional integration.
2. Promote the finance and implementation of sustainable multimodal logistics and corridors to facilitate the development of the bioeconomy, with a strong emphasis on river transport.
3. Scale up green infrastructure standards: implement standards and norms that minimize socio-environmental impact and promote ecosystem-based solutions.
4. Improve the infrastructure and service quality of river transport in the Amazonia region, particularly for the transport of passengers in urban, metropolitan, and isolated areas.

Improving the procurement process is also essential to increasing competition and reducing corruption, as well as reducing renegotiations, cost overruns, delays, and deficient infrastructure. Digital procurement platforms can increase access to information and reduces personal interactions, leading to better outcomes.[24] But implementing digital procurement must be accompanied by efforts to strengthen public sector capacity, ensure effective enforcement of regulations, and expand digital connectivity.[25]

[24] For instance, Lewis-Faupel et al. (2016) found, for the case of India and Indonesia, that although e-procurement did not lead to lower prices, it resulted in significant quality improvements, including better road construction and fewer delays. Moreover, the adoption of e-procurement increased competition, as evidenced by a higher share of contracts being awarded to firms from outside the local area. This is an indication that the system facilitated easier entry for more qualified contractors

[25] On this point, Bosio et al. (2022) analyze public procurement laws, practices, and outcomes across 187 countries and find that stricter procurement regulations are associated with better outcomes. but mainly in countries with low public sector capacity. In contrast, in countries with high public sector capacity, overly rigid rules can hinder the socially optimal use of discretion, such as the ability to screen out low-quality bidders. Hence, tailored solutions that strengthen regulatory enforcement and build the capacity of public officials should be prioritized for the Amazonia Region.

Enhancing land governance and enforcing environmental protections are also important for Amazonia, as they enable property rights and infrastructure development. Clarifying land tenure through transparent and simplified titling processes reduces legal uncertainty and conflicts. It also lays the groundwork for responsible project planning. Initiatives such as Brazil's *Terra Legal* program in Amazonia, begun in 2009, for example, seeks to reduce land disputes and strengthen environmental enforcement by granting legal titles to households that, prior to 2004, had been farming public land for more than five years. For small farmers, the program also requires compliance with the Brazilian Forest Code, which mandates the conservation of 80% of land in Amazonia. The rationale behind this policy is that legal land tenure makes landholders more visible and accountable to regulatory authorities, thereby facilitating the enforcement of environmental regulations and strengthening overall land governance. While it is still too early to assess the long-term impact of this approach on reducing land conflicts and deforestation, short-term evaluations show mixed results. Lipscomb & Prabakaran (2020), for example, finds that outcomes vary depending on the number of registrations per county and the size of the farm. But overall, the authors find, land tenure reform can help create incentives to slow deforestation, especially among small farmers.

Strong cadastral systems and effective enforcement should complement such efforts at titling. In some situations, maintaining an official cadastral database is not feasible because of limited public interest, institutional capacity, or financial resources. Protecting the rights of local populations is nonetheless crucial. In this regard, Peru's Cadastral Information System for Native Communities (SICNA in Spanish) was developed to address the lack of cadastral mapping for Indigenous communities in the Peruvian Amazonia. SICNA is a georeferenced database that compiles geographic and tabular information, helping to fill critical gaps in official land records. While it does not provide legal land titles, SICNA, and initiatives like it, play a vital role in recognizing Indigenous presence, clarifying overlapping land claims, and supporting the resolution of conflicts involving Indigenous territories, concessions, and public lands. In the process, it demonstrates the value of digital registries and geospatial data in strengthening land governance.

4. Conclusions

Despite considerable effort and investment, significant gaps remain in access to transport, electricity, water and sanitation, and digital connectivity in Amazonia. Traditional infrastructure, while still essential for key projects and urban centers, is in some cases technically unfeasible, prohibitively expensive, or environmentally unsustainable for Amazonia. Solutions such as locally based water cistern programs, decentralized solar energy systems, and electrified fluvial transport can serve as alternatives, and can complement traditional infrastructure to improve access and resilience in remote areas. All of this can be achieved through the collaboration of the public and private sectors.

Governance deficiencies remain a critical barrier to improving infrastructure services. Weak institutional capacity, poor coordination between national, subnational and cross-border authorities, and corruption have often led to poorly planned infrastructure projects in Amazonia. Insufficient oversight and enforcement by regulatory bodies have allowed projects to proceed without proper environmental and social assessments, exacerbating deforestation in the process. Inadequate land titling systems have led to an overlap in property rights and land conflicts.

Improving long-term infrastructure outcomes in the region requires stronger regulatory frameworks, increased technical and financial capacity among oversight institutions, and the development of transparent and coordinated planning processes. Ensuring that infrastructure projects are subject to rigorous feasibility studies, competitive procurement, and meaningful consultation with affected communities will help mitigate risks, reduce delays, and enhance the social, economic, and environmental sustainability of investments.

Better data and research also must be generated to provide an up-to-date diagnostic of infrastructure conditions and develop more innovative, context-specific solutions. Such efforts will be critical in the coming years to increasing effective access to infrastructure services for the Amazonia.

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