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Participatory road infrastructure and Sustainable Development Goals: an andean model for sustainable

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Abstract

This article analyzes the Participatory Road Development Plan for Cutervo Province (Peru), focusing on how road strategies can promote local economic development, social equity, and environmental sustainability. Using a participatory methodology and tools such as georeferenced road inventory and geographic information systems (GIS), the study identifies priority routes for intervention and proposes strategies that integrate road connectivity improvement with the promotion of local production, sustainable rural tourism, and environmental management practices. The results show that only 6.5% of the routes are paved, limiting access to basic services and markets and affecting

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the quality of life and economic opportunities of the population. The analysis and discussion of the results reveal the importance of addressing road infrastructure as a key driver of local sustainable development, proposing recommendations for future policies that further integrate the economic, social, and environmental dimensions in road planning.

Keywords: Road infrastructure, sustainable development, community participation, SDGs, Peru.

Infraestructura vial participativa y Objetivos de Desarrollo Sostenible: un modelo andino para la sostenibilidad

Resumen

El presente artículo analiza el Plan de Desarrollo Vial Participativo para la provincia de Cutervo (Perú), enfocándose en cómo las estrategias viales pueden promover el desarrollo económico local, la equidad social y la sostenibilidad ambiental. A través de una metodología participativa y el uso de herramientas como el inventario georreferenciado de carreteras y Sistemas de Información Geográfica (GIS), el estudio identifica las rutas prioritarias para la intervención y propone estrategias que integran la mejora de la conectividad vial con la promoción de la producción local, el turismo rural sostenible y prácticas de gestión ambiental. Los resultados muestran que solo 6,5% de las rutas están pavimentadas, lo que limita el acceso a servicios básicos y mercados, afectando la calidad de vida y las oportunidades económicas de la población. El análisis y discusión de los resultados revelan la importancia de abordar la infraestructura vial como un eje articulador del desarrollo local sostenible, proponiendo recomendaciones para políticas futuras que integren aún más la dimensión económica, social y ambiental en la planificación de infraestructuras viales.

Palabras clave: Infraestructura vial, desarrollo sostenible, participación comunitaria, ODS, Perú.

Introduction

The province of Cutervo, located in the Cajamarca region of Peru, presents a critical paradox in its development trajectory (Tirado et al., 2024). Despite 72% of its population relying on agricultural and livestock activities, only 6.5% of its 2,163.96 km road network is paved (Aguirre et al., 2018). This infrastructural deficit escalates logistical costs by approximately 40% and restricts access to essential services for 65% of rural communities (Jaramillo, 2024). Such structural disconnection not only perpetuates multidimensional poverty affecting 34% of the population but also exacerbates environmental degradation due to unsustainable agricultural practices in hard-to-reach areas (World Bank, 2007).

In response to these challenges, the Participatory Provincial Road Plan (PVPP) 2023–2028 has been initiated as a pioneering strategy aimed at transforming road infrastructure into a catalyst for sustainable development. Unlike traditional policies, the PVPP incorporates three foundational pillars: active community participation in route prioritization, resilient design tailored to mountainous terrains and explicit alignment with Sustainable Development Goals (SDGs): 9 (Industry, Innovation, and Infrastructure) and 13 (Climate Action). This integrative approach seeks not only to enhance physical connectivity but also to strengthen social cohesion and environmental resilience within the region (Vitale & Cotella, 2020).

This study aims to assess the feasibility of the PVPP by proposing a theoretical and practical framework for transforming road infrastructure into a driver of sustainable development in Andean regions. The analysis was included

a review of previous road design experiences in Cutervo, such as the projects in the Cutervo–Angurra, Cutervo–Cullanmayo, and Cutervo–La Conga segments, which have addressed similar challenges related to topography and community involvement. Moreover, the study investigated the impact of informality on road planning, acknowledging that 46.6% of roads lack registration, which significantly hinders the effective implementation of public policies in the region (Quispe et al., 2023).

1. Theoretical background

The evolution of road planning in rural areas has been characterised by a transition from technical-centralist approaches to participatory and ecological models (Kacar, Curic & Ikic, 2016). Theories such as Human Scale Development (Max-Neef) emphasise the necessity of incorporating local priorities into infrastructure (Cameron, 2023), while the Socio-Ecological Systems Approach underscores the interdependence between connectivity and environmental conservation (Ostrom, 2009). The extant literature emphasises the pivotal role of adequate rural road infrastructure in the context of territorial development (Lu et al., 2022). As Ahmed & Eklund (2019) observe, greater accessibility in rural areas can facilitate market access and service utilization, thereby reducing poverty levels, a finding that aligns with the conclusions of Hettige's study. Recent studies demonstrate that the prevalence of local and secondary roads in rural areas (as evidenced by the 88.4% identified in Cutervo) is indicative of the absence of integration with larger networks, thereby constraining economic opportunities (Asher & Novosad, 2020). Furthermore, the absence of road registration, with 46.6% of vehicles unregistered in Cutervo,

complicates the processes of planning and financing, thereby reducing the effectiveness of public policies by 60%, as Asher & Novosad (2020) have observed. With regard to the condition of the roads, Meijer et al. (2018) have indicated that substandard road infrastructure can lead to increased logistics costs and reduced mobility. In this regard, Ahmed & Eklund (2019) emphasize the necessity of paving strategies that are adapted to local conditions in mountainous areas to ensure durability.

Conversely, research has indicated that community involvement in road planning can enhance the sustainability of interventions (Barrett et al., 2017). For instance, Afolabi and Oyetubo (2016) discovered that female participation in road committees enhances project sustainability by 35%. Charlery, Qaim & Smith (2016) demonstrate that enhancing the quality of rural infrastructure has a multiplier effect on development by facilitating access to markets and increasing agricultural productivity. Aguirre et al. (2018) caution that inadequate infrastructure can lead to the isolation of rural communities, thereby amplifying existing inequalities. Finally, Jaramillo (2024) proposes that regional development policies should include not only the construction but also the ongoing maintenance of the road network to promote more equitable development.

In the case of Cutervo, these frameworks are applied in a critical manner. While the PVPP adopts a participatory approach, challenges remain, such as the low representation of women in workshops (only 22% of participants) and the lack of legal incentives to formalize roads. The extant literature supports the necessity of adopting an integrated approach to road planning, combining geo-referenced inventories, multi-criteria prioritization indices (Shrestha, 2025) and

community participation (Saragih et al., 2025) to efficiently target public investment. The Cutervo Participatory Provincial Road Plan incorporates these elements by building on a detailed diagnosis of the existing network and integrating sustainability and equity criteria into its intervention strategies.

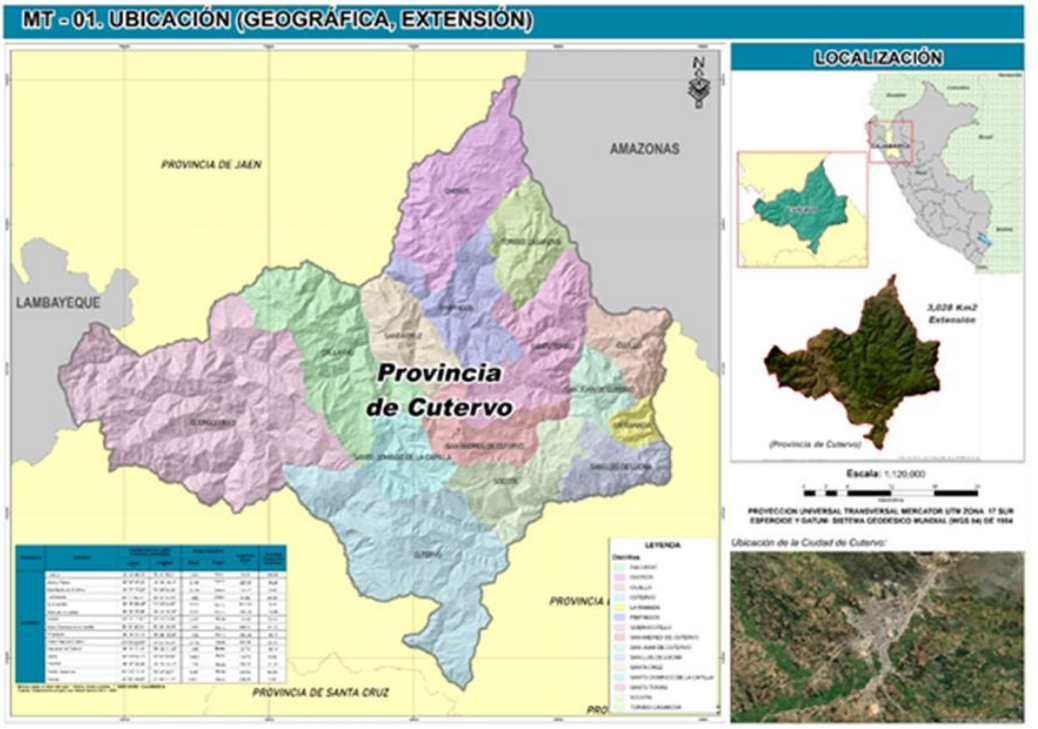
2. Methodology

The study employed a sequential exploratory mixed exploratory design by Creswell (2018), combine: 1. Qualitative phase: A total of 20 participatory workshops were conducted across 15 districts, with a stratified selection process employed to ensure the participation of 150 individuals, including community leaders, farmers, and women. This selection process involved a systematic sampling technique known as snowball sampling. A total of 30 semi-structured interviews were conducted with key stakeholders, including Ministry of Transport Officials and Environmental Non-governmental Organisations (NGOs). 2. Quantitative phase: The georeferencing of 252 routes was conducted using Garmin 64s GPS, with the resulting data subsequently integrated into ArcGIS to calculate accessibility indices. A survey was conducted on 300 households, with a sampling error of 5% and a confidence level of 95%. The objective of the survey was to measure the socio-economic impact. The validity of the study was ensured by the following: Methodological triangulation: A comparison is to be made between workshop data and satellite records. The present study will be subject to external peer review. The present study aims to validate the Road Prioritisation Index (RPI) by the Centre for Andean Studies. Ethical protocols: The issue of informed consent and the anonymity of participants is of paramount importance.

2.1. Geographical location, territorial extension and altitudinal range.

The province of Cutervo is located in the center of the department of Cajamarca, within the coordinates 06º 22' 48.72“south latitude and 78º 49' 58.81” west longitude. Its altitude varies between 1,001 and 2,655 meters above sea level, with the provincial capital located at 2,655 meters above sea level. The territorial extension of the province ranges from 34.82 km² to 687.00 km², with the provincial capital at 431.03 km² (Suárez, 2024).

Figure 1. Location map of the town of Cutervo



source: Suárez, 2024

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The development of the "Participatory Provincial Road Plan of Cutervo 2023-2028" relied on a variety of essential resources for identifying and prioritizing road interventions. One fundamental resource was the Georeferenced Road Inventory, which provided a detailed mapping of the province's network of local and rural roads. Through the use of Global Positioning System (GPS) technology and georeferencing systems, the length, condition, surface type, and connectivity of each route were documented. This data was integrated into a Geographic Information System (GIS), which allowed for a visual representation of routes and intervention areas, facilitating the identification of priority and vulnerable areas in terms of connectivity. To ensure compliance with current regulations, legal documents and guidelines from the Ministry of Transport and Communications and the National Center for Strategic Planning (CEPLAN) were employed, providing the regulatory framework for road planning (Ministerio de Transportes y Comunicaciones, 2017; Suárez, 2024).

The methodology adopted for formulating the PVPP in Cutervo was participatory and decentralized, following several stages. The process began with the collection and analysis of primary and secondary data, including geographic, socioeconomic, and climatic information, which allowed for an assessment of the physical conditions of the roads and associated risks. Subsequently, a situational diagnosis of the road infrastructure was conducted, which enabled an evaluation of the current state of connectivity and the identification of construction and maintenance needs. This diagnosis was supported by a demographic and socioeconomic analysis, using data from the National Institute of Statistics and Informatics (INEI), to identify areas with the greatest

infrastructure deficiencies (Ministerio de Transportes y Comunicaciones, 2017; Suárez, 2024).

A Road Prioritization Index was later developed, evaluating multiple criteria such as access to basic services, connectivity to production centers, and road passability. This index enabled the classification of routes according to urgency and potential economic and social impact. Once the priority interventions were identified, specific proposals for road construction, maintenance, and rehabilitation were formulated, categorizing them into main and secondary routes. For each intervention, technical strategies were defined, considering factors such as the use of appropriate materials and paving solutions for high-demand areas (Ministerio de Transportes y Comunicaciones, 2017; Suárez et al., 2024).

The PVPP also included a monitoring and evaluation scheme, establishing indicators to measure the progress of each intervention. The monitoring is carried out by a Technical Monitoring Team, which periodically assesses the plan's impact in terms of reduced travel times, improved connectivity, and increased traffic flow. Furthermore, sustainability approaches were integrated, incorporating climate change adaptation measures and promoting community participation in the planning and maintenance of road infrastructure. These methods ensure a comprehensive approach aimed at improving Cutervo's connectivity and fostering sustainable socio-economic development in the province (Ministerio de Transportes y Comunicaciones, 2017; Suárez et al., 2024).

2.2. Community participatory approach

The formulation of the Participatory Provincial Road Plan (PVPP) in Cutervo incorporated a participatory approach involving community workshops, surveys, and interviews with local stakeholders, such as farmers' associations, community leaders, and municipal authorities. These efforts were undertaken to capture the community's needs and expectations regarding road infrastructure. The information gathered was integrated into the development of the plan through a monitoring committee composed of community representatives, who provide continuous feedback and oversee the progress of the interventions. In response to community feedback during the workshops, specific routes connecting agricultural communities to regional markets were prioritized, ensuring that the PVPP reflects the economic and social interests of Cutervo's residents.

2.3. Alignment with national policies

The PVPP has been designed in alignment with national development and infrastructure policies, particularly those outlined in the National Competitiveness and Productivity Plan (PNCP) and the Bicentennial Plan. These policies aim to promote infrastructure in rural areas, with the objective of reducing access gaps and fostering social inclusion. Additionally, the PVPP follows the guidelines of the National Center for Strategic Planning (CEPLAN) and the Ministry of Transport and Communications, ensuring that interventions comply with national regulations and support regional development goals. For comparison, the Lambayeque Road Infrastructure Project, 2021-2026 (Suárez et al., 2024), in Peru has significantly improved connectivity and access to regional

markets in rural areas. Similarly, the Cutervo PVPP prioritizes high-demand routes that facilitate mobility and economic growth, demonstrating an approach aligned with these successful cases in the country.

2.4. Methodological process

The development of the Participatory Provincial Road Plan of Cutervo began with preparatory activities, including the formation of a multidisciplinary team composed of engineers, planners, and representatives from the Provincial Municipality of Cutervo, as well as specialists from Decentralized Provías. Partnerships were established with local authorities and civil society representatives to ensure community participation in the planning process. This approach facilitated a better understanding of the province's specific needs and allowed the plan to reflect the expectations of Cutervo's residents. Resources, such as funding, technical equipment, and field personnel, were also allocated for the project's development (Ministerio de Transportes y Comunicaciones, 2017)

The second phase consisted of gathering secondary information based on strategic plans, such as the Regional Concerted Development Plan of Cajamarca. Logistic corridors connecting Cutervo to regional and national markets, as well as the main production chains, particularly in the agricultural and livestock sectors, were also analyzed. This analysis helped identify key routes and areas where improved connectivity would enhance local economic development (Ministerio de Transportes y Comunicaciones, 2017)

Subsequently, a detailed provincial diagnosis was conducted through a georeferenced road inventory that documented the existing network of roads.

With the support of GPS devices and GIS systems, the length, condition, and surface type of each road were recorded. Socioeconomic and demographic data from the National Institute of Statistics and Informatics (INEI) were also considered to map areas with the greatest infrastructure needs. The connectivity gap was calculated in terms of access to basic services, such as education and healthcare, identifying zones that required either rehabilitation or new roads (Ministerio de Transportes y Comunicaciones, 2017).

Finally, a Rural Road Prioritization Index was developed, evaluating criteria such as economic competitiveness and access to services. This allowed for the classification of routes into primary and secondary categories and the establishment of specific interventions for construction, maintenance, and rehabilitation. To implement the plan, a multi-year schedule was designed with goals and potential funding sources, including options for private participation, such as Works for Taxes. The methodological process also included a monitoring and evaluation scheme to measure the impact of interventions, focusing on sustainability and long-term environmental management (Ministerio de Transportes y Comunicaciones, 2017).

3. Results

3.1. Road system and road surface

The analysis of the provincial road network revealed that Cutervo has 252 registered roads. Of these, 10.8% are classified as national roads, 0.8% as departmental roads, and 88.4% as local roads. In the neighbourhood network (communal and rural roads), 41.8% of the roads have been officially registered, while 46.6% have not been registered. The total length of the provincial road

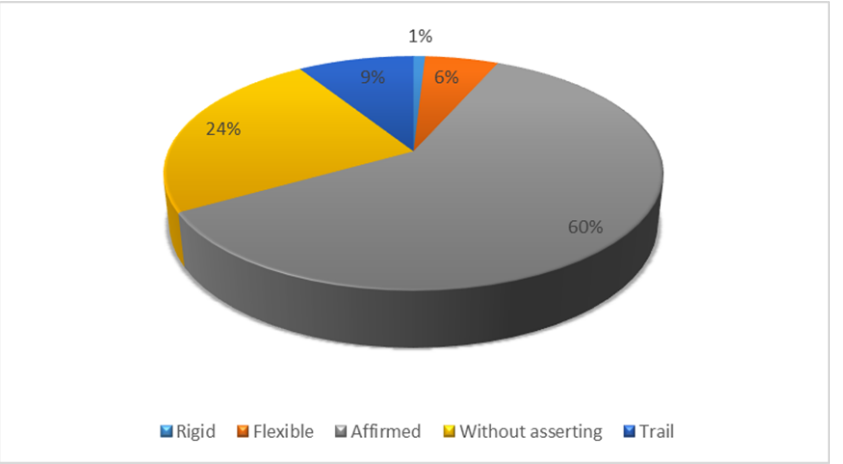
system is 2,163.96 km. Of the total number of roads, only 6.5% are surfaced with asphalt, 59.8% are surfaced with stabilised earth pavement, 24.5% are unimproved (i.e. beaten earth), and the remaining 9.2% are trails or footpaths. The data suggest that the network is predominantly unpaved, a factor that significantly impacts trafficability, particularly during the rainy season. (Table 1).

Table 1. Route classifier by surface type

Type of road network	Nº of routes	Length (Km.)	Type of surface (Km.)					%
			Pavement		Affirmed	Without asserting	Trail	
			Rigid	Flexible				
National	3	233.203	5.165	101.713	126.325	-	-	9.6%
Departmental	1	16.802	-	-	16.802	-	-	0.7%
Neighborhood	**319**	**2,169.174**	**21.623**	**27.878**	**100.656**	**67.679**	**1,951.338**	**89.7%**
. Registered	75	923.436	19.163	26.593	56.480	0.274	820.926	38.2%
Not registered	244	1,245.738	2.4600	1.285	44.176	67.4050	1,130.4120	51.5%
TOTAL	**323**	**2,419.18**	**26.788**	**129.591**	**243.783**	**67.679**	**1,951.338**	
Percentage		**100.0%**	**1.1%**	**5.4%**	**10.1%**	**2.8%**	**80.7%**	
Source: Own elaboration								
Baseline information: Georeferencedsurvey of the road network of the Province of Cutervo								

Source: own elaboration (2025)

Figure 2. Type of surface of the Province of Cutervo



source: Own elaboration (2025)

3.2. Social and economic impact or impact evaluation

The social impact of the Cutervo PVPP is reflected in improved access to basic services. Reduced travel times will facilitate access to healthcare and education services, allowing residents to reach emergency medical services and advanced educational opportunities, thereby promoting social inclusion and human development. From an economic standpoint, the plan aims to stimulate the local economy by providing adequate road infrastructure for the transport of agricultural and livestock products. An improvement in agricultural productivity is anticipated in the areas benefiting from the PVPP, due to reduced logistical costs and direct access to broader regional markets. These projections underscore the fundamental role of road infrastructure in strengthening the local economy and supporting sustainable development in the province.

3.3. Analysis and discussion of the results

The analysis of the road network in the province of Cutervo reveals a predominance of secondary roads, which constitute 88.4% of the 252 roads identified. This distribution reflects a common phenomenon in rural areas, where, as Shrestha (2025) emphasizes, the prevalence of feeder roads indicates a lack of integration into broader road networks, limiting both connectivity and economic opportunities. In Cutervo's case, the low proportion of national and departmental roads suggests a disconnection that could hinder regional development by restricting access to markets and essential services.

A concerning aspect is that 46.6% of Cutervo's rural roads are unregistered, a situation that aligns with the findings of Barrett et al. (2017). These authors argue that the lack of road registration is a critical issue in rural areas, where informality complicates effective planning and access to maintenance funds. This issue is further aggravated by the absence of precise data, making it difficult to implement adequate and sustainable infrastructure policies.

Regarding surface quality, only 6.5% of Cutervo's roads are paved, while 24.5% remain unpaved, findings that are similar to those of Schweikert et al (2014). They emphasize that poor road quality in rural areas is linked to higher transportation costs, reduced access to services, and decreased mobility. Additionally, the lack of pavement affects the local economy and may negatively influence road safety. Jiménez, Bolívar & Segrera (2020) also suggest that unpaved roads pose a significant risk to users due to their propensity for deterioration and adverse weather conditions.

The heterogeneity in pavement types also underscores the challenges of investment in road infrastructure in Cutervo. Gómez & Oviedo (2025) indicate that investment in rural infrastructure is insufficient, perpetuating the cycle of poverty by limiting access to markets and services. In the context of Cutervo, this lack of investment is concerning, as improvements in road infrastructure could significantly impact poverty reduction and economic development. Moreover, the uneven distribution of pavement types may relate to a lack of infrastructure policies adapted to local conditions. Chong, Qin and Chen (2019) stress that in mountainous areas like Cutervo, road policies must consider geographic and climatic characteristics to ensure road durability. The high proportion of unpaved roads suggests a need to review and adapt infrastructure strategies to better meet local needs.

Conversely, Aguirre et al. (2018) highlight that community involvement in road planning and maintenance can enhance road sustainability in rural areas. In Cutervo, including local communities in decision-making processes could be an effective strategy for improving the road network and ensuring its long-term maintenance.

In terms of economic impact, Apurv & Uzma (2021) indicate that improving road quality can have a multiplier effect on rural development, facilitating market access and increasing agricultural productivity. The current situation in Cutervo, with a road network largely unpaved and unregistered, represents untapped potential that could be activated through strategic infrastructure investments. Useche et al. (2024) also note that inadequate road infrastructure in rural areas contributes to community isolation, exacerbating economic and social inequalities. In Cutervo, the large number of unpaved and

unregistered roads is a clear example of how poor infrastructure can perpetuate the isolation and marginalization of rural communities.

Finally, Madiasworo (2018) propose that regional development policies include a comprehensive vision, not only focused on construction but also on the continuous maintenance of existing infrastructure. In Cutervo, such a policy could be key to enhancing connectivity and promoting more equitable and sustainable economic development. In this regard, the PVPP incorporates alternative paving technologies adapted to the mountainous geography of the region, using local materials and low-cost techniques that facilitate long-term maintenance. Additionally, the plan considers innovative financing options, such as 'Works for Taxes' and Public-Private Partnerships, allowing private sector involvement to ensure financial sustainability and promote inclusive and sustainable development.

Conclusion or concluding remarks

The analysis of the road network in the province of Cutervo highlights a predominantly rural structure, characterized by limited connectivity regarding national and departmental routes. With 88.4% of roads classified as rural and 46.6% of these unregistered, there is a lack of formalization that hinders proper management and maintenance of this infrastructure. This situation not only limits accessibility within the province but also restricts socioeconomic development opportunities, as it hampers access to basic services, production centers, and markets.

In terms of surface type, only 6.5% of roads are paved, while 59.8% are classified as gravel roads, and 24.5% are unpaved, with an additional 9.2%

categorized as trails. Although gravel road coverage is substantial, the lack of adequate paving reveals insufficient road infrastructure to support traffic and improve circulation safety, especially in rural areas. The considerable proportion of unpaved roads underscores the need for interventions to ensure safe and efficient transit.

These findings emphasize the urgency of implementing public policies focused on formalizing and improving the road network in Cutervo, with a particular emphasis on paving and registering rural roads. In doing so, not only would connectivity and accessibility within the province be promoted, but also more equitable and sustainable economic growth would be fostered, integrating rural communities and improving the quality of life for the inhabitants.

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