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The Impact of Trans Papua Road Infrastructure on Local Business Growth in Nduga Regency

Gay Murib[1*], Halomoan Hutajudu[2], Elsyan R. Marlissa[3]
Faculty of Economics and Business, Universitas Cendrawasih, Jayapura, Papua, Indonesia[1,2,3]
malldalimunthe@gmail.com

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Abstract

Purpose: This study examines the impact of road infrastructure development on local business growth in Nduga Regency, Papua Highlands, Indonesia, and explores community perceptions of its economic benefits and its sustainability.

Research Methodology: A qualitative descriptive approach, complemented by quantitative analysis (Likert scale), was used to gather primary data from 30 respondents in the Kenyam District, including micro and small entrepreneurs, traders, and community members. Five key informants from the Regional Public Works Agency (PUPR), Bappeda, and community leaders provided additional insights through interviews. Secondary data were obtained from official statistics and government documents from 2019 to 2024.

Results: The results show consistently high community ratings across all economic impact indicators, with 83.33% of respondents rating income improvement as "very good," followed by market expansion and trading fluency at 80.00%. Key informant interviews confirmed that road development reduced the prices of basic goods, facilitated trade, and created new business opportunities. Despite these improvements, 79.4% of regency-level roads remain unpaved, and income gains are constrained by limited capital and incomplete road access.

Conclusions: The study concludes that road infrastructure is a significant catalyst for economic growth but requires complementary investments in village roads, capital access, and the inclusive participation of Indigenous communities.

Limitations: This study had limitations, such as a small sample size and reliance on self-reported data.

Contribution: This study provides insights for policymakers and highlights the challenges faced by Indigenous Papuans, offering a foundation for future research on infrastructure development in underserved regions.

Keywords*: Community Perception, Economic Growth, Frontier Development, Local Business Development, Nduga Regency, Papua, Road Infrastructure, Trans Papua Road.*

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1. Introduction

Infrastructure investment is one of the most extensively studied channels through which governments seek to accelerate regional economic development. Roads, as the most fundamental component of transport infrastructure, connect isolated communities to markets, reduce transaction costs, facilitate the movement of goods and labor, and create conditions under which private investment becomes viable. Indonesia has explicitly recognized this dynamic through its National Strategic Projects program (Proyek Strategis Nasional), under which successive governments have prioritized road network expansion in historically under-connected regions. Among the most ambitious of these initiatives is the

Trans Papua Highway, a planned 4,300-kilometre network traversing the length of New Guinea, whose principal rationale is to break the deep isolation that has long impeded development in Papua's mountainous interior (Ndun, 2024).

Nduga Regency, located in the Papua Highlands Province (Provinsi Papua Pegunungan), illustrates the developmental consequences of isolation in its most extreme form. The regency, established in 2008 following the separation from Jayawijaya Regency, covers approximately 12,941 km², of which 70% is steep mountainous terrain. Prior to road construction, virtually all inter-district movement depended on air transport, with consequent high costs for all goods traded. The Human Development Index (HDI) for Nduga stood at just 37.68 in 2023, the lowest of any regency in Indonesia, while the poverty rate reached 37.09% in 2023, a figure that, remarkably, has trended upward from historical levels despite successive budgetary investments (Prionggo, Djaenuri, Lukman, & Sinurat, 2020). The Gross Regional Domestic Product (GRDP) in 2024 totalled approximately IDR 1.63 trillion, ranking 504th of 514 Indonesian regencies and cities, with a per-capita GRDP of approximately IDR 14.37 million.

The Trans Papua segment traversing Nduga links Wamena, Habema, Kenyam, and Mumugu across approximately 175 kilometres. However, as of 2024, significant infrastructure deficits remain: 79.4% of regency-administered roads are still unpaved dirt roads; a 4 km gap near the Mumugu border disrupts full southern connectivity; and the road is subject to seasonal damage from landslides and flooding, particularly along the Kenyam–Habema Corridor. Against this backdrop, a critical empirical question arises: to what extent has existing road development in Nduga generated measurable economic benefits at the local community level, and through which specific mechanisms does it occur? (Nababan, Rante, & Rusim, 2022).

This question is both theoretically and practically significant in several ways. Theoretically, the Nduga case tests the predictions of growth theory particularly Harrod-Domar's investment-growth nexus, Solow's capital accumulation model, and Rostow's 'take-off' prerequisites in an extreme frontier context where complementary conditions (human capital, institutional capacity, market integration) are exceptionally limited. If road investment generates economic benefits even under these conditions, the case for infrastructure-led development in frontier regions is bolstered (Abdurakhmonovich 2025). Practically, this study generates evidence directly applicable to infrastructure prioritization, community engagement strategies, and complementary program design for the Papua Highlands (Hikmatovna, 2025).

This study provides novel insights into the impact of road infrastructure development on regional economic growth in Nduga Regency, Papua, by addressing the gap in empirical research on infrastructure-led development in frontier regions with severe isolation and limited resources. While existing studies have explored the broader effects of infrastructure investment, few have examined its specific economic benefits at the local community level in remote and underdeveloped areas, such as Nduga. This study contributes to growth theory by testing investment-driven models, such as Harrod-Domar's investment-growth nexus and Solow's capital accumulation, in an extreme frontier context where human capital and institutional capacity are limited. The findings offer practical implications for policymakers in the Papua Highlands, particularly in terms of infrastructure prioritization, community engagement strategies, and designing complementary programs that can maximize the developmental impact of road investment in similarly isolated regions.

This study addresses two specific research questions: (1) What is the current condition of road infrastructure development in Nduga Regency? (2) What are the perceived and actual impacts of road infrastructure development on local businesses and economic growth? This study focuses on the Kenyam District, the regency capital, which serves as the primary hub of economic activity and the most direct beneficiary of road construction. The remainder of this paper is organized as follows. Section 2 reviews the relevant theoretical and empirical literature. Section 3 presents the research methodology used in this study. Section 4 describes the research sites of the study. Section 5 reports the results. Section 6 discusses the findings in relation to the existing literature and their policy implications. Section 7 concludes.

2. Literature Review and Hypothesis/es Development

2.1 Road Infrastructure as Productive Capital

The foundational economic rationale for public road investment derives from the treatment of infrastructure as productive capital, a factor of production that enhances the productivity of private inputs, reduces transaction costs, and generates positive externalities beyond the direct users of a facility. In a seminal empirical contribution to this literature, Fraga and Ferreira-Filho (2024) demonstrate that public infrastructure investment is a major determinant of private sector productivity in the United States, with roads and highways contributing disproportionately to total factor productivity growth. Subsequent research, while subjecting Aschauer's estimates to methodological scrutiny, has broadly confirmed the positive relationship between infrastructure investment and economic output (Sahoo & Dash, 2009).

In developing countries, road infrastructure serves an additional function: market integration (Barzin, D'Costa, & Graham, 2018; Zeng, Liao, & Wang, 2025). Where roads are absent or of very poor quality, markets are fragmented: producers cannot access buyers, consumers cannot access goods and services, and both face elevated prices reflecting transportation costs and risks (Heeres, Tillema, & Arts, 2016). Banerjee, Duflo, and Qian (2020) provide a landmark study from China demonstrating that proximity to transportation networks significantly predicts economic growth, although they note that the causal mechanism operates primarily through expanded market access rather than through the direct employment effects of construction. Rosik and Wójcik (2022) extend this framework to document the 'wider economic and spatial impacts' of road investment, including induced changes in agglomeration patterns, labour market integration, and land use.

For Indonesia, Warsilan and Noor (2015) confirm the positive contribution of infrastructure to economic growth in Samarinda, Indonesia. Hanum, Syahputra, and Sea (2025) demonstrate, in a national panel study, that national and provincial roads generate more significant growth impacts than regency roads, a finding attributable to the broader market integration effects of higher-order network connections. Murib, Sondegau, Lestari, and Taime (2024), in research directly adjacent to the present study, quantify that each additional kilometre of road in Puncak Regency (Nduga's neighbouring regency) is associated with approximately 0.2 percentage points of additional economic growth.

2.2 Road Infrastructure in Lagging Regions: Theory and Evidence

The theory of lagging region development emphasizes that infrastructure investment, while necessary, is not sufficient to generate sustainable economic transformation in areas characterized by weak institutions, limited human capital, geographic remoteness, and social conflict (Palilu & Suripatty, 2018). Rostow's stage theory places infrastructure investment as a prerequisite for the 'take-off' transition, but explicitly conditions that transition on broader institutional and human capital readiness (Muda, Nurlina, & Nuradi, 2020). In practice, infrastructure in frontier regions may generate smaller multiplier effects than in better-connected areas if complementary factors such as capital markets, skilled labor, and stable governance are absent (Kurniawan & Aminata, 2023).

Kambu, Jinca, Pallu, and Ramli (2022) provide the most directly relevant prior study for the Nduga context. Examining community perceptions of the Trans Papua Road, they found significant divergence between Indigenous Papuan (OAP) and non-OAP communities. OAP respondents perceived limited benefits and expressed concerns about the adequacy of community participation in planning and implementation, while non-OAP respondents and government officials assessed the impacts more positively. This finding anticipates the central complexity of the present study and underscores the importance of disaggregating community perceptions by ethnicity and occupation. Tambunan (2023) demonstrates that road availability and quality are key determinants of micro, small, and medium enterprise (MSME) performance and market reach in remote areas. However, the mechanisms through which infrastructure benefits translate to specific community groups depend critically on whether those groups have the capital, skills, and social networks to exploit the expanded market access that infrastructure provides. Where these complementary assets are absent, as they often are in areas such as Nduga, the principal beneficiaries of infrastructure may be external traders and transporters rather than indigenous residents.

2.3 Economic Growth Indicators in the Infrastructure Context

Measuring the economic impact of road infrastructure at the local level requires attention to multiple indicators beyond aggregate GRDP (Li et al., 2020). In frontier regions with limited market integration, the most immediate and directly observable effects operate through specific transmission channels: reduced transportation costs, improved goods distribution, expanded buyer reach, market price stabilization, income increases for traders and service providers, and the emergence of new business opportunities (Martuscelli & Gasiorek, 2019). These intermediate indicators, which can be assessed through community surveys, provide richer and more policy-relevant information than aggregate statistics.

Prapti, Suryawardana, and Triyani (2015) applied this multi-indicator approach in a study of the impact of road infrastructure on small-scale enterprises, finding significant improvements in customer volume, goods distribution fluency, transportation cost reduction, and business income. Ompusunggu (2018) corroborates these findings in a Likert-scale study in Karo Regency, confirming positive associations between road construction and all key economic activity indicators. The present study applies a comparable multi-indicator approach to the Nduga context.

Table 1. summarizes the key empirical studies informing this research.

Author (Year)	Location / Focus	Method	Key Finding
Ompusunggu (2018)	Semangat Gunung Village, Karo Regency	Quantitative, simple linear regression	Road construction positively and significantly increased community business activity, goods distribution, and household income.
Pertiwi, Adelia, and Fatmasari (2022)	Sonomartani Village	Quantitative, multiple regression	Road construction improves economic mobility, expands market reach, and reduces the transportation costs.
Banerjee et al. (2020)	China (regional panel data)	Econometric difference in differences	Road access positively contributes to regional economic growth, and the magnitude depends on the initial area conditions.
Hanum et al. (2025)	Indonesia (national/provincial roads)	Regression panel data	National and provincial roads have a more significant growth impact than Regency roads.
Hewada, Iek, and Kreuta (2019)	Papua Province	Regression analysis	Road infrastructure has proven to improve the efficiency and volume of inter-regency trade in Papua.
Tambunan (2023)	Remote areas (SMEs)	Qualitative, quantitative	Road availability and quality are key factors in improving SME performance and market reach.
Kambu et al. (2022)	Nduga Regency (Trans Papua)	Qualitative	The Trans Papua Road project was not fully accepted by the local OAP community, and there was

			limited community involvement in planning.
Putra and Rajiman (2025)	Talang Kelapa, Banyuasin	Quantitative, multiple regression	Road quality improvement significantly accelerated local economic growth through improved accessibility and employment opportunities in the region.
Nasution (2025)	Rural communities	Quantitative, survey regression	Better roads increase market participation, open business opportunities, and strengthen local economic diversification.

Several consistent findings have emerged in the comparative literature. First, road infrastructure improvements consistently generate positive community perceptions of economic benefits across a wide range of indicators. Second, the magnitude of these benefits is moderated by complementary conditions, particularly capital access, human capital quality, and institutional capacity. Third, indigenous communities in frontier regions tend to perceive more limited benefits than non-indigenous and government stakeholders, reflecting their differential capacity to seize economic opportunities. Fourth, market expansion and income improvement are typically the most strongly perceived benefits, whereas the effects of job creation tend to be more heterogeneous. These patterns directly inform the interpretation of Nduga's findings.

3. Methodology

3.1 Research Design

This study employed a mixed methodological approach that combined qualitative and quantitative descriptive analyses. The qualitative component, centered on in-depth interviews with key informants and field observations, provides contextual and interpretive depth, capturing the institutional, historical, and community-level dynamics that shape the impact of infrastructure. The quantitative component, based on Likert-scale questionnaire data, provides a systematic and comparable measurement of community perceptions across ten economic impact indicators. The two components were integrated through triangulation, with the interview findings used to contextualize, explain, and validate the survey data patterns.

Qualitative data from interviews were analyzed using Miles and Huberman's (1994) interactive model, comprising three iterative stages: data reduction (selective coding and thematic organization of interview transcripts), data display (narrative matrices and thematic summaries), and conclusion drawing and verification (cross-source and cross-method triangulation). Quantitative survey data were analysed descriptively through Likert score frequencies and percentages for each indicator, with findings interpreted in relation to the five-point rating scale: Very Good (5), Good (4), Fair (3), Poor (2), Very Poor (1).

3.2 Study Site

The study was conducted in the Kenyam District, the administrative and economic capital of Nduga Regency in Papua Highlands Province. Kenyam serves as the terminus of the most developed segment of the Trans Papua Road (Wamena–Kenyam corridor) and is the primary site of market activity, government services, and commercial enterprise in the regency. Therefore, it is the location most directly affected by road infrastructure development and is best positioned to provide informative community perceptions of the economic impacts. Data will be collected from November to December 2025.

3.3 Sampling and Respondents

Purposive sampling was employed to select 30 primary respondents from the economically active population of the Kenyam District. The selection criteria required respondents to be engaged in economic activities directly dependent on road infrastructure, including traders, kiosk and food stall operators, motorcycle taxi drivers, farmers selling produce, and timber entrepreneurship. The sample was designed to capture the perspectives of communities most directly affected by road-related changes in transportation costs, goods distribution, and market access. Additionally, five key informants were selected from institutional positions with direct knowledge of road infrastructure planning, implementation, and community impact: two officials from the Nduga Regional Public Works Agency (PUPR), two from the Regional Development Planning Agency (Bappeda), and one community leader from Kenyam District. Table 2 summarizes the respondents' characteristics of the study.

Table 2. Respondent profile

Characteristic	Category	n	Percentage (%)
Gender	Male	17	56.67
	Female	13	43.33
Age Group	25–35 years	5	16.67
	36–46 years	10	33.33
	47–57 years	11	36.67
	58–68 years	4	13.33
Education Level	Primary school (SD)	3	10.00
	Junior high (SMP)	8	26.67
	Senior high (SMA)	12	40.00
	Diploma (D1–D3)	4	13.33
	University (S1–S3)	3	10.00
Ethnicity	Indigenous Papuan (OAP)	20	66.67
	Non-OAP	10	33.33
Occupation	Civil servant (PNS)	3	10.00
	Small trader / kiosk / food stall	12	40.00
	Restaurant owner	5	16.67
	Timber entrepreneur	2	6.67
	Motorcycle taxi (ojek)	4	13.33
	Farmer	4	13.33
Total		**30**	**100.00**

The sample reflects the demographic characteristics of Kenyam's economically active population: predominantly male (56.67%), in the middle productive age groups (36–57 years, 70.00%), with secondary education as the modal category (SMA, 40.00%), and predominantly Indigenous Papuan (OAP, 66.67%). Occupational distribution captures the key economic sectors that are most directly affected by road access: small trade, transport services, food services, agriculture, and timber.

3.4 Data Sources

Primary data were collected using two instruments. First, a structured Likert-scale questionnaire comprising ten indicator items was used to assess community perceptions of road conditions and economic impact across dimensions, including physical road quality, transport accessibility, goods distribution, trading activity, transportation cost changes, buyer volume, price stability, market expansion, income changes, and new employment/business creation. Second, semi-structured in-depth interviews with the five key informants explored road development planning, implementation quality, budget allocation, policy coordination between the central and regional governments, and community perspectives on the social and economic impacts. Secondary data encompassing GRDP trends, road length and surface condition data, population characteristics, poverty rates, and HDI scores were obtained from BPS Nduga, Dinas PUPR Nduga, and regional planning documents (RPJMD and RKPD) for 2019–2024 period.

Nduga Regency covers approximately 12,941 km² of predominantly mountainous terrain in Papua Highlands Province, bordered by Lanny Jaya and Puncak Jaya to the north, Yahukimo and Jayawijaya to the east, Asmat to the south, and Mimika to the west. The regency comprises 32 districts and 248 villages. The topographic conditions are extreme, with more than 70% of the territory comprising steep gradients, with elevations ranging from 200 to 3,000 m above sea level (with some peaks reaching 5,000 m). These conditions severely constrain ground-based connectivity, making many districts accessible only by air prior to road construction and maintenance activities.

Human development indicators place Nduga among Indonesia's most challenged regencies. The HDI of 37.68 in 2023 is the lowest nationally; 79.51% of the population has not completed any formal schooling and 37.09% live below the poverty line. The population of approximately 112,173 (2024) is predominantly indigenous Papuan and is engaged primarily in subsistence agriculture, principally sago, sweet potato, and traditional cultivation. The working-age population (15–59 years) constitutes 89.63% of the total population, representing a significant potential labor resource whose full mobilization is constrained by limited education and access to the market.

3.5 Road Infrastructure Conditions

The Trans Papua Highway traverses the Nduga Regency along the Wamena–Habema–Kenyam–Mumugu corridor, covering approximately 175 km within the regency. Table 3 presents the current road network by administrative authority and surface type in the study area.

Table 3. Road infrastructure conditions by administrative authority, Nduga Regency (2024)

No.	Type of Surface	Regency (km)	Province (km)	National (km)
1	Asphalt (Paved)	29.91	0.00	4.00
2	Gravel	0.10	51.977	0.00
3	Dirt (Unpaved)	115.45	42.182	0.00
Total		**145.46**	**94.159**	**4.00**

The data reveal significant infrastructure quality deficits. Of the 145.46 km of regency-administered roads, 115.45 km (79.4%) remain unpaved and are highly susceptible to seasonal damage. A further 42.18 km of province-administered roads were unpaved. Only 4 km of the nationally administered road are fully paved. The 51.98 km provincial gravel road provides intermediate-quality connectivity. This dominance of low-quality surfaces, despite the progress represented by the establishment of a physical road corridor, directly limits the economic benefits that road access can generate, as dirt roads become impassable or dangerous in wet weather and generate high vehicle operating costs.

At the study site in Kenyam District, conditions are somewhat better than the regency average: 10.00 km of paved asphalt road and 13.30 km of gravel road have been completed, with no unpaved dirt road remaining on the primary Kenyam corridor. This relatively better local condition helps explain the positive community perceptions recorded in the survey, while clarifying the spatial boundary within which these perceptions apply. The benefits are concentrated in and around the regency capital and have not yet extended uniformly to more distant districts.

3.6 Economic Context

Nduga's economy is characterized by heavy dependence on government expenditure and the construction sector. The construction sector contributed 28% of the GRDP in 2024, largely reflecting public infrastructure investment, while agriculture (subsistence farming and agroforestry) contributed 28.74%. The total GRDP is expected to reach IDR 1.63 trillion in 2024, representing a per-capita GRDP of approximately IDR 14.37 million, which is significantly below the national average. Economic growth was recorded at 3.56% in 2024, which is a modest improvement over the pandemic-affected year.

Despite this growth, open unemployment remains exceptionally low (0.07% in 2024), reflecting not full employment but rather the dominance of subsistence and informal economic activity, in which virtually

all working-age adults are engaged in survival-oriented production activities. The private formal sector is minimal; most market activity is conducted by non-Indigenous migrants who dominate the trader and entrepreneur segments of Kenyam's economy. This structural feature has important implications for who captures the economic benefits of road infrastructure, a question that the survey and interview data directly address in this study.

4. Results and Discussions

4.1 Road Infrastructure Conditions: Community Perceptions

Survey respondents evaluated three dimensions of road infrastructure quality in the Kenyam District. Regarding the physical condition of the road surface (asphalt/quality), 50.00% rated it as very good, 33.33% as good, and the remaining 16.67% rated it as poor. No respondents recorded poor or very poor ratings. Regarding the ease of land transport access, 66.67% rated it as very good and 20.00% as good. Regarding the road's contribution to smooth goods distribution and business outputs, 73.33% rated it as very good and 16.67% as good.

These consistently positive ratings reflect the tangible improvement in road conditions that have occurred in the Kenyam District, where a combination of asphalt-paved and gravel road surfaces has replaced the previously all-dirt conditions. Key informant interviews corroborated this assessment: Dinas PUPR officials confirmed that the Kenyam corridor has received prioritized investment, reducing typical travel times to Wamena from five hours or more to approximately five hours on the primary route with considerably improved reliability. The head of Bappeda's infrastructure division noted that the connection to Wamena, previously accessible only by irregular and expensive charter flights, now allows ground transport that, while still challenging, represents a fundamental shift in accessibility.

4.2 Economic Impact Indicators: Survey Findings

Table 4. Community perceptions of road infrastructure's economic impact (n = 30)

No.	Indicator	Very Good (%)	Good (%)	Fair (%)
1	Physical road condition (asphalt/surface quality)	50.00	33.33	16.67
2	Ease of land transport access	66.67	20.00	10.00
3	Smoothness of goods distribution and business outputs	73.33	16.67	10.00
4	Fluency of trading activities	80.00	13.33	6.67
5	Impact on transportation costs (freight reduction)	66.67	26.67	6.67
6	Impact on number of buyers/customers	60.00	23.33	16.67
7	Impact on price stability of goods	66.67	23.33	10.00
8	Impact on market expansion / business growth	80.00	13.33	6.67
9	Impact on income from business/employment	83.33	16.67	0.00
10	Impact on creation of new jobs and business opportunities	56.67	30.00	13.33

Several patterns in these data merit detailed discussion. The income impact indicator recorded the strongest positive response in the entire survey: 83.33% of respondents rated the impact of road conditions on their business or employment income as very good, with the remaining 16.67% rating it as good, and no responses in the lower three categories. This finding suggests that the economic benefits of road improvement have been directly felt in monetary terms by community members engaged in market-based activity.

Market expansion and trading fluency were tied as the second-strongest indicators, each recording 80.00% very good ratings. These high ratings reflect the road's role in connecting Kenyam traders to a broader customer base and enabling more frequent and reliable commercial transactions. Prior to improved road access, the high cost and limited availability of air freight effectively restricted the volume and variety of goods in the Kenyam market, constraining both supply and demand. Transportation cost reduction, price stability, and ease of transport access each recorded 66.67% very good ratings, which were still strongly positive but reflected that the benefits in these dimensions, while

real, were less uniformly transformative than income and market access effects. The creation of new jobs and business opportunities recorded the lowest very good rating of the group (56.67%), while still drawing 30.00% good ratings, suggesting that while new opportunities have emerged, the pace and scale of business creation remain limited relative to the potential implied by infrastructure access.

4.3 Qualitative Findings: Key Informant Perspectives

In-depth interviews with PUPR officials, Bappeda planners, and community leaders provided important context for the survey findings. All institutional informants confirmed that road development had generated measurable economic benefits: basic commodity prices had declined, trade flows had increased, and new small-scale businesses had emerged along the Kenyam corridor as the paving work progressed. The Bappeda infrastructure head estimated that rice prices, which previously reached IDR 20,000–25,000 per kilogram in Kenyam due to the cost of air freight, had declined to IDR 12,000–15,000 per kilogram following improved ground transport, representing a 25–40% reduction in staple food costs.

However, the community leader informant representing the Indigenous Nduga community of Kenyam offered a more nuanced assessment. While acknowledging visible improvements such as road and bridge construction and the reduction in basic goods prices, this informant highlighted that access to kampung (village) roads connecting residential areas to the main Kenyam road remains severely limited: 'The main road is getting better, but from the kebun [garden] to the road, we still struggle the path is narrow and in the rainy season it is completely impassable.' This observation points to a critical gap in the infrastructure network: while the primary Kenyam corridor has been substantially improved, the last-mile connectivity linking residential villages and agricultural production areas to the corridor remains underdeveloped.

The community leader further observed that while food prices had become more affordable, community members' incomes had not risen proportionally: 'Goods are cheaper, yes. But our income has not gone up because we don't have capital to expand our business.' This finding captures a core dynamic of frontier infrastructure economics: road access reduces consumption costs for all community members, regardless of income or occupation, but generating income gains requires additional capacity capital, skills, and market knowledge to exploit expanded business opportunities. For OAP community members who typically lack access to formal credit and may have limited trading experience, access to infrastructure is necessary but insufficient for income improvement.

4.4 Discussion

4.4.1 Road Infrastructure as a Catalyst: Confirming the Theoretical Predictions

The overwhelming positivity of community survey responses, with no respondents rating any indicator as poor or very poor and strong majorities rating multiple indicators as very good, provides robust empirical support for the theoretical proposition that road infrastructure development acts as a catalyst for economic growth, even in extreme frontier conditions. The specific transmission mechanisms identified in the theoretical literature, such as reduced transportation costs, improved goods distribution fluency, expanded market access, and new business opportunities, were all confirmed as operative in the Nduga context.

These findings align closely with those of prior empirical studies. The pattern of results mirrors Ompusunggu (2018) findings in Karo Regency, Prapti et al. (2015) multi-indicator assessment, and Nasution (2025) survey-based evidence, all of which find consistently positive associations between road quality improvement and the full range of local economic activity indicators. The Nduga case thus extends this evidence base to a considerably more challenging governance and geographic context, strengthening the generalizability of the infrastructure-growth relationship. The finding of a 3.56% GRDP growth rate in 2024, while modest in absolute terms, represents meaningful positive momentum for a regency that only a decade ago had negligible market activities. The dominant role of the construction sector (28% of GRDP) reflects the direct economic stimulus of ongoing road investment, while the agriculture sector's contribution (28.74%) increasingly reflects access to markets that allow subsistence-oriented production to generate a commercial surplus.

4.4.2 The Last-Mile Gap and Differential Benefit Distribution

A critical finding of this study, which complements and contextualizes the positive survey results, is the distinction between primary road corridor and last-mile connectivity effects. The strong positive perceptions recorded by the survey respondents in the Kenyam District reflect the real improvements achieved in the primary Kenyam road segment. However, the community leader's qualitative testimony reveals that the kampung-level connector roads linking residential and agricultural areas to the main corridor remain severely underdeveloped.

This last-mile gap has significant distributional impact. Community members most likely to benefit from the primary road are traders with fixed market stalls in Kenyam Town, motorcycle taxi drivers operating on the main road, and food stall operators serving travelling customers. They predominantly operate in formal and semi-formal economies. Community members most constrained by the last-mile gap are subsistence farmers attempting to bring garden produce to market, and residents of remote kampung are disproportionately Indigenous OAP households. The result is a pattern of unequal benefit distribution that mirrors Kambu et al. 's(2022) finding of divergent OAP and non-OAP perceptions of the benefits of the Trans Papua Road.

This finding has important theoretical implications. This suggests that in frontier regions, the aggregate positive relationship between road infrastructure and local economic growth is real and measurable but conceals within-community distributional dynamics that aggregate statistics miss. The full realization of infrastructure's inclusive development potential requires not only the construction of primary road corridors but also systematic investment in village connector roads and agricultural access paths that bring the road's benefits within reach of the most marginalized community members.

4.4.3 The Capital Constraint: Infrastructure Without Complementary Assets

The community leader's observation that 'goods are cheaper, but income has not increased because we lack capital' encapsulates a well-established constraint in the frontier infrastructure literature. Road access expands market opportunities and reduces input costs, but converting these conditions into income gains requires the capacity to act on them: working capital to purchase stock, skills to manage trading operations, and social networks to build a customer base. Where these complementary assets are absent, as they commonly are in OAP households that have historically engaged in subsistence rather than market-oriented production, infrastructure access alone is insufficient to generate income improvement. This finding is consistent with Tambunan (2023) finding that road quality and MSME performance are positively linked, but with important moderation by the availability of capital. This also aligns with the broader development economics literature, which suggests that infrastructure investment in lagging regions is most effective when combined with complementary programs supporting financial inclusion, entrepreneurship training, and market linkage development. In the Nduga context, this implies that road investment should be accompanied by accessible microcredit programs, agricultural marketing cooperatives, and vocational training initiatives targeting OAP community members.

4.4.4 Policy Implications

The study's findings have five concrete policy implications for Nduga Regency's infrastructure and economic development strategies. First, the prioritization of last-mile connectivity kampung connector roads and agricultural access paths should be elevated, alongside primary corridor development. The primary benefits of the Kenyam road are real but concentrated; expanding them requires connecting outlying communities to the main road network.

Second, road maintenance should be institutionalized. Current GRDP growth is strongly driven by construction investment (28% of GRDP); however, this source of growth will decline as road networks are completed. Establishing routine and periodic maintenance systems funded through dedicated regional budget allocations is essential to preserve infrastructure stock and sustain its economic benefits over time. Third, complementary economic development programs are needed to enable OAP community members to capture the benefits of infrastructure. These include accessible microcredit facilities with culturally appropriate guarantee mechanisms, agricultural extension services connecting

smallholders to Kenyam market channels, and vocational training in small-business management targeting OAP youth.

Fourth, Indigenous community participation in infrastructure planning and implementation must be strengthened. Kambu et al. (2022) finding — that OAP communities feel insufficiently involved in Trans Papua Road planning remains relevant. Genuine participatory planning would help align road development priorities (including last-mile connector priorities) with community needs and improve the program's social acceptance. Fifth, multi-sector integration should be pursued: the economic potential unlocked by road development in Nduga will be maximized when complementary investments in education, health, and market infrastructure co-evolve with road network expansion rather than being planned and budgeted in isolation.

5. Conclusions

5.1 Conclusion

This study generated empirical evidence on the micro-level economic impact of road infrastructure development in Nduga Regency, Papua Highlands Province, one of Indonesia's most geographically isolated and developmentally challenged regions. The findings confirm that road infrastructure development serves as a significant catalyst for local economic growth, operating through multiple specific channels: improved transport accessibility, reduced freight costs, facilitated goods distribution, expanded market reach, stabilized commodity prices, increased business income, and the creation of new employment and business opportunities in the area. Survey evidence is unambiguous: across all ten impact indicators, zero respondents recorded poor or very poor ratings, and strong majorities, particularly for income improvement (83.33% very good), market expansion (80.00% very good), and trading fluency (80.00% very good), assessed road development's economic contribution as very good.

However, these positive overall findings are qualified by two important limitations identified through qualitative evidence. First, a critical last-mile connectivity gap persists: while the primary Kenyam corridor has been substantially improved, kampung-level connector roads linking residential villages and agricultural production areas to the main road remain severely underdeveloped, constraining the spatial reach of infrastructure benefits. Second, capital constraints limit OAP community income gains: while road development reduces consumption costs for all community members, generating income improvement requires complementary assets, working capital, business skills, and market access that OAP households typically lack. Road infrastructure is necessary but insufficient for inclusive economic transformation in frontier regions. The policy conclusion is clear: sustained, inclusive economic development in Nduga requires a dual-track strategy that combines continued primary road network completion with systematic investment in village connector roads, complementary economic empowerment programs for OAP communities, and strengthened Indigenous participation in infrastructure planning. Road investment is a powerful starting point, but only an integrated approach will realize its full transformative potential for the people of Nduga.

5.2 Research Limitations

This study had several limitations. The study's sample of 30 respondents, while appropriate for qualitative descriptive purposes and adequate for Likert-scale descriptive analysis, does not support inferential statistical generalization to the full population of Kenyam or to other Nduga districts. While the purposive sampling design captures informant-rich perspectives, it introduces a potential selection bias toward more economically active community members. The study's spatial focus on the Kenyam District limits its applicability to more remote districts, where infrastructure conditions and, therefore, economic impacts differ substantially from the regency capital.

5.3 Suggestions and Directions for Future Research

Future research directions include longitudinal studies tracking economic indicator changes before and after road completion across multiple Nduga districts, comparative studies across Trans Papua Road segments to assess how infrastructure quality (asphalt versus gravel versus dirt) moderates economic impact, quantitative econometric analysis using GRDP panel data to estimate causal road–growth

relationships, and community welfare studies disaggregating impacts by ethnicity, gender, and occupation to rigorously assess distributional equity.

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Author Contributions

The authors contributed collectively to the study's development and execution. GM conceptualized the study, designed the research methodology, and led data collection. HH performed the data analysis, particularly the qualitative and quantitative assessments, and contributed to the interpretation of the results. ERM provided substantial input for the literature review, assisted with data collection, and contributed to manuscript writing and revisions. All authors critically reviewed and approved the final manuscript, ensuring that the research findings were comprehensive and accurately reflected the study objectives.

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