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The Impact of Transportation Accessibility Disparities on Inter-Regency Municipal Economic Inequality in Gorontalo Province from a Defense Economics Perspective

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Abstract

This paper examines how unequal land transport access affects economic disparity across the regencies and municipalities of Gorontalo Province, and what those gaps mean for defense economics. We apply a quantitative spatial method that combines the Spatial Accessibility Index (Ai), road network performance metrics (Volume Capacity Ratio and road condition ratings), Vehicle Operating Cost (VOC) simulations, the Williamson Index (IW), and Klassen Typology. Secondary data come from Gorontalo Provincial Government records: Governor Decree No. 21/18/I/2026 on Provincial Road Status (423.18 km), technical traffic assessments by the Provincial Transportation Agency, the 2023–2027 Road Traffic and Transportation Safety Action Plan (RAK LLAJ), and the National Disaster Risk Assessment (KRB). Road access splits sharply between the urban centers (Gorontalo City and Gorontalo Regency) and the outlying regencies (Pohuwato, Boalemo, Bone Bolango, and North Gorontalo). Severe road damage concentrates in Bone Bolango (63.10 km) and Boalemo (45.40 km). Uneven intercity public transport (AKDP) coverage and frequent Over Dimension Over Loading (ODOL) violations in the western corridor (71.5% at the Marisa weighing station) widen the physical gap. When road links fail, VOC rises by 77% to 85%, and the gap in baseline Human Development Index (HDI, 2021) and per capita spending grows between Gorontalo City (HDI 77.41) and outlying areas such as North Gorontalo (HDI 65.21) and Pohuwato (HDI 65.80). For defense economics, poor transport links and regional inequality create structural weaknesses, strain non-military logistics, and keep local adaptive capacity low (Regional Resilience Index/IKD of 0.28–0.37) along the Indonesian Archipelagic Sea Lane (ALKI) II buffer zone. Dual-use (civil-military) infrastructure and priority maintenance of primary collector roads can narrow regional economic gaps and support territorial defense.

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1. INTRODUCTION

Roads move crops to market and link farming villages to trade centers, which ties a regional economy together [1]. For national defense, a transport network also has to be judged on whether it keeps regions from drifting apart, because socio-economic stability

underpins national resilience [2], [3]. Regions with balanced access tend to recover faster from economic shocks. Where roads and public transport services cluster in a few hubs, rural poverty deepens and territorial weak points appear, and these weaken non-military defense within Indonesia's Total People's Defense and Security System (Sishankamrata) [4] and [5].

Gorontalo Province lies on the northern arm of Sulawesi. The Sulawesi Sea and the international shipping lane of the Indonesian Archipelagic Sea Lane (ALKI) II border it to the north, and Tomini Bay to the south. Agriculture, Forestry, and Fisheries produce 37.48% of its Gross Regional Domestic Product (GRDP). Wholesale and Retail Trade follows at 11.88%, then Construction (10.78%), Public Administration and Defense (7.28%), and Transportation and Warehousing (5.72%) [6]. The outlying regencies grow most of the agricultural and fishery commodities, so they need reliable, well-maintained, and safe roads to reach logistics hubs.

Field data show a wide access gap between the urban core and the outlying border regencies. Gorontalo City, the provincial capital, covers 79.59 km², or 0.71% of the province's 11,257.07 km², yet holds 2,510 people/km². Pohuwato Regency, on the western border with Central Sulawesi, sits at the other end: 4,244.31 km² (37.70% of the province) and only 35 people/km² [7]. Road quality deepens the divide. Governor Decree No. 21/18/I/2026 updated the status of the Primary Collector Road-2 (JKP-2) and Primary Collector Road-3 (JKP-3) networks, which cover 423.18 km in 50 segments connected to 748.60 km of national roads. Even so, only 57.28% of provincial roads are in good or fair condition, and 42.72% are poor or badly damaged. Most severe damage sits in the outlying regencies, above all Bone Bolango (63.10 km severely damaged) and Boalemo (45.40 km).

Public transit, road safety equipment, and freight loads show the same split. Several main roads in downtown Gorontalo City carry Degree of Saturation (DJ) values above 0.85, and the city holds 10,399 motorized pedicabs (Bentor), 41.28% of the 25,193 units in the province. Remote sub-districts in North Gorontalo, Pohuwato, and Bone Bolango lack adequate Intercity Within-Province (AKDP) bus and minibus service, and some rural routes have only one to three vehicles [8]. In the western corridor, overloaded trucks wear down roads in Pohuwato fast: the Marisa Motor Vehicle Weighing Station (UPPKB) found that 71.5% of inspected freight trucks broke Over Dimension Over Loading (ODOL) limits. Steep terrain (68.63% of the province has slopes above 40%) pushes traffic onto one main corridor, a single spine network. When roads fail, or floods and landslides strike [9], outlying regencies risk physical isolation and sharp rises in transport costs.

These gaps affect living standards and regional income. According to Statistics Indonesia [6], the Human Development Index (HDI) reaches 77.41 in Gorontalo City, compared to only 65.21 in North Gorontalo and 65.80 in Pohuwato. In defense economics, persistent inequality and weak connectivity in coastal and border regions pose a serious non-military security risk: poor road networks reduce regional resilience, delay defense logistics and disaster relief, and keep the Regional Resilience Index (IKD) low during emergencies. Existing studies on national road vulnerability [10], macroeconomic impacts of transport disruptions [11] and road resilience to natural hazards [12] mainly focus on physical or macro-level network disruptions. Similarly, Indonesian studies on inter-district road infrastructure and spatial inequality [13] examine economic convergence without addressing territorial defense readiness, while previous regional analysis in Gorontalo has focused specifically on how land transport vulnerability exacerbates disaster risk [14] Few studies link district-level road access gaps to both regional economic inequality and territorial defense in an Indonesian province. This study fills that gap with three aims: (1) to measure disparities in road infrastructure and land transport services across Gorontalo's

regencies and municipalities; (2) to estimate how road access gaps and transport costs drive inter-regency economic inequality; and (3) to propose transport infrastructure policies that support both regional equity and territorial defense.

2. METHOD

This study applies quantitative spatial analysis and regional economic methods to test how land transport access relates to regional economic inequality, and what that relationship means for territorial defense. It covers all six administrative areas of Gorontalo Province: Gorontalo City and the regencies of Gorontalo, Bone Bolango, Boalemo, Pohuwato, and North Gorontalo.

2.1. Data Sources

This study utilizes secondary spatial, engineering, operational, macroeconomic, and disaster-risk datasets compiled from official authorities across all six administrative jurisdictions of Gorontalo Province:

1. Provincial Road Network Hierarchy: Gorontalo Governor Decree No. 21/18/I/2026 on Primary Collector Road-2 (JKP-2) and Road-3 (JKP-3) Networks (benchmarked against Governor Decree No. 383/18/XI/2017).
2. Traffic Safety Action Plan: The 2023–2027 Road Traffic and Transportation Safety Action Plan (RAK LLAJ) of Gorontalo Province (Ministry of Home Affairs & Provincial Transportation Agency).
3. Traffic Engineering & Capacity Data: The 2023 Final Technical Report on Traffic Engineering Management, Road Safety Facility Needs, and Accident-Prone Areas (Provincial Transportation Agency).
4. Inter-Regency Transit Network: Gorontalo Governor Regulation No. 40 of 2017 (as amended by Regulation No. 46 of 2019) on the 33-corridor Inter-City Within Province Public Transport (AKDP) Route Network.
5. Road Transport Service Evaluations: Road Transport Division Performance Evaluation Reports (*Evaluasi Kinerja Bidang Angkutan Jalan*, Provincial Transportation Agency), covering AKDP trials, Bus Rapid Transit (BRT), and pioneer transport (*angkutan perintis*).
6. Transport Node Performance: Operational records of the Limboto Type B Passenger Terminal (*Terminal Tipe B Limboto*) and complementary intermodal hubs (Isimu and Dungingi Type A Terminals, Gorontalo Port, Anggrek Port, and Djalaluddin Airport).
7. Institutional Planning & Spatial Frameworks: The 2023–2026 Strategic Plan (Renstra), Government Agency Performance Reports (LKIP), and 2026 Amended Performance Agreements of the Provincial Transportation Agency, alongside regional spatial/transport masterplans (RTRW/Tatrawil).
8. Macroeconomic & Demographic Series: Regency and municipal Gross Regional Domestic Product (GRDP), population, and Human Development Index (HDI) longitudinal series from BPS-Statistics of Gorontalo Province for estimating the Williamson Index (IW).
9. Disaster Risk & Territorial Resilience: The 2022–2026 National Disaster Risk Assessment (KRB, BNPB) and 2023–2027 Provincial Disaster Management Plan (RPB, BPBD of Gorontalo Province) for spatial hazard overlay.

2.2. Analytical Model of Transportation Accessibility and Logistics Costs

We evaluate accessibility in each regency and city with three measures: road density and condition ratios, road segment and intersection performance under the Indonesian

Highway Capacity Manual (PKJI) [15] and the Spatial Accessibility Index (Ai). Ai follows a standard spatial gravity formulation [16] and [17]

$$Ai = \sum nj = 1 \, (Wj \, / \, dij\beta \,) \qquad (1)$$

where Ai is the spatial accessibility index of regency/city i, Wj is the capacity weight of logistics hubs and economic centers j (Gorontalo Port, Anggrek Port, Kwandang Port, Dungingi Type-A Terminal, Isimu Type-A Terminal, and Djalaluddin Airport), dij is the road travel distance or travel time from i to j adjusted for road surface conditions and terrain slope, and β is the distance decay parameter.

We measure road traffic performance with the Degree of Saturation (DJ / Volume Capacity Ratio), the ratio of observed traffic volume (q) to actual road capacity (C):

$$D_J = q/C = \frac{q}{C0 \times FCLJ \times FCPA \times FCHS \times FCUk} \qquad (2)$$

To estimate how poor road surfaces and steep grades affect freight transport costs across districts, we simulate Vehicle Operating Costs (VOC / BOK) per kilometer for two standard freight vehicles (Medium Trucks and Heavy Fuso Trucks) across four provincial corridors:

$$VOC_total = VOC_fixed + (VOC_variable \times \alpha) \qquad (3)$$

where α is the cost multiplier for damaged road surfaces (light or severe damage) and steep gradients (θ > 40%), plus forced detours around blocked main roads. In this study, the distance decay parameter is set at $\beta = 0.015$ min^{-1}based on inter-district road travel-time impedance, while hub capacity weights W_j reflect the relative passenger and freight throughput capacity of each provincial logistics node. For the VOC simulation in Equation (3), the cost multiplier αincorporates pavement distress penalties (light and severe road damage), gradient resistance on slopes exceeding 40%, and detour distance factors

2.3. Analytical Model of Regional Economic Inequality

To measure economic inequality across the six regencies and municipalities in Gorontalo Province, we calculate the population-weighted *Williamson Index (IW*) [18], [19]:

$$I_W = \frac{\sqrt{\sum_{i=1}^{n} (y_i - \bar{y})^2 \cdot (f_i/n)}}{\bar{y}} \qquad (4)$$

where IW is the Williamson Index (0 < IW < 1, with higher values indicating greater inter-district inequality), yi is per capita GRDP or welfare level in district i, ȳ is the provincial average, fi is the population of district i, and n is the total provincial population. We also apply a Klassen Typology that compares each district's economic growth rate and per capita expenditure with the provincial means. Quadrant I combines above-average growth and expenditure; Quadrant II, below-average growth with above-average expenditure; Quadrant III, above-average growth with below-average expenditure; and Quadrant IV, below-average values on both.

2.4. Defense Economics and Territorial Defense Evaluation

In the final step, we link the transport and inequality findings to territorial defense planning through three defense economics criteria:

1. **Strategic Supply Chain Resilience (Defense Logistics Security):** We assess how dependence on a single main road corridor (single spine network), compared with backup routes (network redundancy), affects the movement of food, fuel, and defense personnel.

2. **Socio-Economic Deterrence:** We examine how income and HDI gaps shape the Regional Resilience Index (IKD) and social stability in outlying districts.
3. **Dual-Use Infrastructure Planning:** We identify road segments and transport terminals that can carry daily civilian trade in peacetime and support emergency or defense logistics in a crisis.

Because operational military logistics movement data are classified and unavailable in open public records, this evaluation adopts a non-military defense economics approach using civil-military supply chain vulnerability (single-spine dependency), strategic energy and port asset exposure, and the BNPB Regional Resilience Index (IKD) as operational proxies for territorial readiness.

3. RESULTS AND DISCUSSION

3.1. Disparities in Road Network Infrastructure and Transportation Services Across Regencies/Municipalities

Spatial mapping and policy records show that land transport in Gorontalo Province depends on a single primary arterial spine (748.60 km of national roads) along the northern and southern coasts, fed by provincial collector roads. Governor Decree No. 21/18/I/2026 (issued January 19, 2026) [20] reorganized the provincial road network (JKP-2 and JKP-3) into 50 segments totaling 423.18 km. It replaced Governor Decree No. 383/18/XI/2017, which had listed 467.17 km of provincial roads and 176.44 km of provincial strategic roads . The 2026 decree added key connector roads to transport hubs and public facilities, including access roads to Panua Pohuwato Airport (9.09 km), Pohuwato Port (7.28 km), Limboto Terminal (0.76 km), and Ainun Regional Hospital (0.36 km).

Because disaggregated district-level condition audits for the 2026 network (423.18 km) are still being finalized, Table 1 presents the baseline district breakdown under the prior 2017 inventory (467.17 km), which already reveals sharp disparities in road density and surface condition across districts.

Table 1. Disparities in Regional Dimensions, Provincial Road Conditions, and Road Safety Facilities by Regency/Municipality

Regency / Municipality	Area (km²)	Population Density (People/km²)	Existing Provincial Road Length (km)	Good & Fair Condition Roads	Lightly & Severely Damaged Roads	Existing vs. Required Safety Facilities (Units)**
Gorontalo City	79.59	2,510	43.14	35.01	8.13	1,037 Existing / 170 Needed
Gorontalo Regency	1,750.83	226	110.79	88.09	22.70	978 Existing / 830 Needed
Bone Bolango Regency	1,984.31	83	137.58	56.88	80.70	1,315 Existing / 275 Needed
Boalemo Regency	1,521.88	97	112.00	48.40	63.60	280 Existing / 621 Needed
Pohuwato Regency	4,244.31	35	54.46	33.01	21.45	19 Existing / 152 Needed
North Gorontalo Regency	1,676.15	75	9.20	6.20	3.00	28 Existing / 40 Needed
Provincial Total	**11,257.07**	**105**	**467.17**	**267.59**	**199.58**	**3,657 Existing / 2,088 Needed**

Source: Authors' compilation (2026) from BPJN, DPUPR-Pkp Provinsi Gorontalo, BPTD Class II Gorontalo, and Dishub Provinsi Gorontalo.

*Note : ** District-level provincial road length and surface condition figures reflect the baseline inventory under Governor Decree No. 383/18/XI/2017 (totaling 467.17 km), as segment-level condition breakdowns following the reclassification under Governor Decree No. 21/18/I/2026 (423.18 km) are still undergoing disaggregated*

assessment. Road safety facilities comprise streetlights, warning signs, and guardrails compiled from the 2023–2027 RAK LLAJ technical audit.

Table 1 shows three physical disparities:

- **Uneven Road Surface Conditions:** Gorontalo City and Gorontalo Regency have the best provincial roads, with 81.15% and 79.51% in good or fair condition. The outlying regencies fare far worse. In Bone Bolango, 58.66% of provincial roads (80.70 km, including 63.10 km severely damaged) are in poor or badly damaged condition; in Boalemo the share is 56.79% (63.60 km, including 45.40 km severely damaged).
- **Low Road Density and Missing Safety Equipment in Outlying Areas:** Pohuwato Regency (37.70% of the province's land area) and North Gorontalo Regency (14.89%) have very few provincial collector roads to connect inland farming villages with the Trans-Sulawesi highway. Safety equipment (streetlights, warning signs, and guardrails) follows the same pattern. Bone Bolango holds the most (1,315 units), followed by Gorontalo City (1,037) and Gorontalo Regency (978). Provincial roads in Pohuwato have only 19 installed units, a deficit of 152, and Boalemo has 280 units and needs 621 more.
- **Contrasting Traffic Loads and Modal Split:** Moving Car Observer (MCO) surveys and PKJI 2023 capacity checks put average travel speed at 23.82 km/h in Gorontalo City and its surroundings. Peak-hour traffic downtown nears capacity; on Jl. H.B. Jassin the Volume Capacity Ratio (VCR) exceeds 0.89 (Level of Service E). Rural collector roads such as Jl. Kamboja (DJ = 0.12) and Jl. Thayeb M. Gobel (DJ = 0.18) carry little traffic, but they are narrow and steep and lack safety barriers.

Public transit and freight enforcement show similar imbalances (Table 2).

Table 2. Disparities in Transport Mode Distribution, Vehicle Roadworthiness Testing, and Freight Load Violations

Regency / Municipality	Bentor Fleet Population (Units)	AKDP (Units)	Active Mandatory Inspection Vehicles (Units)	Primary Transportation & Logistics Nodes	Operational Bottlenecks & Freight Load Issues
Gorontalo City	10,399	226	6,656	Gorontalo Port, Ferry Port, Dungingi Type-A Terminal	High density of 39.57 bentor/km; road conflict between port container trucks and city traffic.
Gorontalo Regency	7,925	326	7,360	Djalaluddin Airport, Isimu Type-A Terminal, Planned Limboto Type-B Terminal	Heavy roadside friction from Limboto spillover market; main regional transit hub.
Bone Bolango Regency	3,984	60	2,573	UPPKB Molotabu, Southern Coastal & Suwawa Corridors	Vehicle inspection unit (UPUBKB) not fully accredited; 439 violations recorded at UPPKB Molotabu (2021).
Boalemo Regency	1,035	84	2,158	Tilamuta Port	Only 59.36% of commercial vehicles passed periodic inspection (1,281 units); landslide-prone hilly roads.
Pohuwato Regency	1,701	70	1,699	Bumbulan Ferry Port, Panua Airport, UPPKB Marisa	71.5% violation rate at UPPKB Marisa (6,646 of 9,294 trucks), with 78.3% involving ODOL trucks (5,202 units).
North Gorontalo Regency	149	79	950	Anggrek Cargo Port, Kwandang Port, PLTU Anggrek	Very few active AKDP buses (Tolinggula/Papualangi

					served by 1–3 units); steep northern coastal terrain.
Provincial Total	25,193	845	21,396	2 Type-A Terminals, 6 Ports, 2 Airports, 2 UPPKB	Widespread informal transit use & rapid pavement damage from ODOL trucks.

Source: Compiled from the Gorontalo Province RAK LLAJ 2023–2027 Document and BPTD Region XXI Gorontalo records.

Formal bus and minibus service is thin, so residents rely on motorized pedicabs/Bentor (25,193 units) and unlicensed black-plate passenger cars (798 units) (Table 2). Of the 845 licensed AKDP intercity vehicles on fixed routes, most serve medium-distance corridors such as Gorontalo–Tilamuta (91 units) and Gorontalo–Paguyaman (71 units). By district, Gorontalo Regency has the most AKDP units (326, or 38.58% of the 845), followed by Gorontalo City (226, or 26.75%); Bone Bolango has just 60 (7.10%) although it covers 17.63% of the province's land area. Distant rural routes get almost nothing: Papualangi in North Gorontalo (205 km), Sumalata–Tolinggula (194 km), and East Biluhu–Ilomata have only 3, 12, and 1 active units, respectively. As passengers shift to informal transport, the Dungingi and Isimu Type-A Terminals run far below capacity and handle only about 20 interprovincial (AKAP) bus departures on a typical morning.

Heavy trucks put the largest load on the outlying regencies. Weighbridge records from BPTD Region XXI at UPPKB Marisa in Pohuwato Regency show that 6,646 of the 9,294 freight trucks weighed in 2021 (71.5%) broke regulations, and 5,202 of those violators (78.3%) carried overloads (ODOL). Continuous ODOL traffic on the western and northern corridors, combined with limited maintenance funds, speeds up pavement failure in Pohuwato, Boalemo, and Bone Bolango.

3.2. Impact of Accessibility Disparities on Logistics Costs and Inter-Regency/Municipal Economic Inequality

Damaged surfaces in outlying districts, steep terrain (slopes above 40%), and the lack of backup routes raise Vehicle Operating Costs (VOC / BOK) for freight operators [21], Table 3 reports the VOC simulation results for the four main transport corridors of Gorontalo Province.

Table 3. Simulation of Vehicle Operating Cost (VOC) Disparities and Logistics Impacts Across Regional Corridors

Regional Spatial Corridor	Regency / Municipality Coverage	Logistics Fleet Type	Normal Fuel Consumption (km/L)	Damaged Road / Disaster Fuel Consumption (km/L)	Normal Condition VOC (IDR/km)	Disrupted / Detour Condition VOC (IDR/km)	VOC Increase (%)
Central Corridor (Agglomeration)	Gorontalo City – Telaga – Limboto (Gorontalo Regency)	Medium Truck Fuso (Heavy)	5.2 – 5.8 3.0 – 3.2	3.0 – 3.5 1.8 – 2.0	IDR 6,000 – 7,000 IDR 10,000 – 11,500	IDR 10,500 – 12,500 IDR 17,500 – 21,000	+77% +79%
Western Corridor (Trans-Sulawesi)	Isimu (Gorontalo Reg.) – Tilamuta (Boalemo) – Marisa (Pohuwato)	Medium Truck Fuso (Heavy)	5.0 – 5.5 2.8 – 3.0	2.8 – 3.2 1.6 – 1.8	IDR 6,200 – 7,500 IDR 10,200 – 11,800	IDR 11,000 – 13,500 IDR 18,000 – 22,500	+79% +84%
Eastern Corridor (Hinterland)	Kabila – Suwawa – Tulabolo (Bone Bolango Regency)	Medium Truck Fuso (Heavy)	4.8 – 5.2 2.6 – 2.8	2.5 – 2.9 1.5 – 1.7	IDR 6,500 – 8,000 IDR 10,500 – 12,500	IDR 12,000 – 14,500 IDR 19,000 – 23,500	+83% +85%
Northern Corridor (Coastal/Port)	Kwandang – Atinggola – Tolinggula (North Gorontalo Regency)	Medium Truck Fuso (Heavy)	4.5 – 5.0 2.2 – 2.8	2.2 – 2.6 1.4 – 1.6	IDR 6,800 – 8,500 IDR 11,000 – 13,500	IDR 12,500 – 15,000 IDR 20,000 – 24,500	+80% +82%

Source: Authors' calculations based on VOC simulations and spatial network data for Gorontalo Province (2026).

Table 3 shows that even in normal weather and traffic, VOC per kilometer in the Northern Corridor (North Gorontalo) and Eastern Corridor (Bone Bolango) runs roughly 7% to 18% above the Central Corridor (Gorontalo City–Limboto), because of steep grades and long stretches of broken pavement. When floods, landslides, or bridge failures close a main road segment, trucks detour 45 to 120 km and lose 2.5 to 6.5 hours. Under these conditions VOC rises by 77% to 85%. Based on standard regional payload conversions of these simulated VOC increases, estimated freight tariffs climb from IDR 150,000–250,000/ton to IDR 380,000–650,000/ton, which translates into an estimated 18% to 35% price pressure on basic consumer goods in outlying districts during prolonged corridor disruptions. . Indirect costs of this kind grow with hazard exposure [22].

Higher transport costs and weaker connectivity widen income and human development gaps between districts over time (Table 4).

Table 4. Matrix of Economic Indicators, Human Development, and Regional Capacity Inequality Across Regencies/Municipalities

Regency / Municipality	2021 Economic Growth Rate (%)	Adjusted Per Capita Expenditure (IDR Million/Year)	Life Expectancy (Years)	Mean Years of Schooling (Years)	Human Development Index (HDI)	Klassen Typology Classification (Accessibility & Economy)
Gorontalo City	2.81%	12.39	72.53	10.37	77.41 (High)	Quadrant I: Advanced and Fast-Growing (Core Urban Center)
Gorontalo Regency	2.42%	9.85	68.12	7.82	67.34 (Medium)	Quadrant III: Fast-Growing but Lower Spending (Primary Transit Hub)
Bone Bolango Regency	2.18%	10.15	69.45	8.45	70.25 (High)	Quadrant IV: Relatively Lagging (Constrained by Road Damage)
Boalemo Regency	2.03%	8.94	67.20	7.00	66.42 (Medium)	Quadrant IV: Relatively Lagging (High Road Damage)
Pohuwato Regency	2.20%	9.32	64.30	7.45	65.80 (Medium)	Quadrant IV: Relatively Lagging (Peripheral Resource Area)
North Gorontalo Regency	2.20%	9.10	66.15	7.30	65.21 (Medium)	Quadrant IV: Relatively Lagging (Isolated Coastal Corridor)
Gorontalo Province	**2.41%**	**10.25**	**68.07**	**7.92**	**69.00 (Medium)**	**Williamson Index (IW) ≈ 0.11 (low overall spending disparity)**

Source: Compiled from BPS-Statistics of Gorontalo Province BPS Provinsi Gorontalo (2023)

Table 4 links transport access to district-level development outcomes. Using per capita expenditure as the welfare measure and population estimates from Table 1 (density × area), the population-weighted Williamson Index (I_W) comes to about 0.11. While this indicates a relatively low disparity in purchasing-power-adjusted household spending, structural inequality remains pronounced in human capital and adaptive capacity, as

reflected by the 12.20-point HDI gap and lower IKD scores in outlying regencies. The gaps in HDI and resilience scores between Gorontalo City and the outlying regencies remain large:

a. **Growth Concentration in the Urban Core (Quadrants I & III):** Gorontalo City has the highest spatial accessibility score (Ai = 100%) and the best road surface ratio (81.15% good or fair). It also leads the province in economic growth (2.81%), per capita expenditure (IDR 12.39 million/year), average schooling (10.37 years), and HDI (77.41). Gorontalo Regency, home to Djalaluddin Airport and the Trans-Sulawesi junction at Isimu–Limboto, also grows faster than the provincial average (2.42%).
b. **Lagging Welfare in Outlying Regencies (Quadrant IV):** Boalemo (56.79% of provincial roads damaged), Pohuwato (the farthest from the capital and hit hard by ODOL damage), and North Gorontalo (very few provincial collector roads) have the worst road access, and all three fall into Quadrant IV (lagging districts). Boalemo's per capita spending is IDR 8.94 million/year, IDR 3.45 million below Gorontalo City, and its average schooling is 7.00 years. North Gorontalo has the lowest HDI in the province (65.21); Pohuwato has the lowest life expectancy (64.30 years). High transport costs cut farmgate margins for corn, coconut, and fishery producers in these three regencies, and most of the trade surplus shifts to wholesalers and retailers in Gorontalo City (a classic backwash effect).

3.3. Strategic Implications from a Defense Economics and Territorial Defense Perspective

In defense economics, regional inequality and fragile transport links affect territorial resilience and non-military defense readiness as much as they affect civilian budgets. Under Law No. 3 of 2002 on State Defense and the Sishankamrata doctrine, regional spatial planning and transport networks belong to the Supporting Component of national defense. The BNPB Disaster Risk Assessment [23] , the 2023–2027 Provincial Disaster Management Plan, and Provincial Transportation Agency road audits together point to three implications for Gorontalo Province:

a. Logistics Bottlenecks and Single-Spine Network Fragility

Gorontalo Province lies south of the Sulawesi Sea and the ALKI II international shipping lane, but its land network is fragile: one linear highway corridor carries almost all traffic, with very few parallel backup routes. Cascading failures are a known risk in logistics networks of this kind [24], and lost resilience carries economic costs [11]. In the west (Pohuwato and Boalemo) and east (Bone Bolango), the main road squeezes between steep slopes (above 40%) and degraded river basins prone to flash floods and landslides. On the northern coast, the Anggrek Steam Power Plant (PLTU), Anggrek Cargo Port, and Kwandang Port sit in high-risk tsunami, high-wave, and landslide zones; potential tsunami losses in North Gorontalo alone reach an estimated IDR 137.20 billion, the highest in the province.

In the urban core (Gorontalo City and Limboto), mixed traffic slows freight to and from Gorontalo Port: heavy container trucks share narrow streets with thousands of Bentor and roadside market stalls. Provincial Transportation Agency counts (2023) put the Volume Capacity Ratio (VCR) on a main container street, Jl. Sultan Botutihe, at 0.879 (Level of Service E). A maritime security incident along ALKI II or a major natural disaster could remove a single bridge or road section in Bone Bolango, Boalemo, or North Gorontalo. That one loss would cut off districts, disrupt fuel and power operations at PLTU Anggrek, and stall military supplies and disaster relief. Strategic highways carry the same single-point risk in contested logistics settings [25]

b. Low Regional Adaptive Capacity and Human Security Risks

Economic gaps from poor transport access also limit how well local governments and households cope with emergencies, and rural road networks carry social vulnerability as well as physical risk [14], [26]. The BNPB National Disaster Risk Assessment (2022) gives Gorontalo Province an overall Regional Resilience Index (IKD) of 0.51 (Moderate), but district scores in the outlying areas fall far lower (Table 5).

Table 5. Correlation Matrix of Accessibility Disparities, Multi-Hazard Potential Losses, and Regional Defense/Resilience Capacity Index

Regency / Municipality	Regional Resilience Index (IKD)	Regional Capacity Score	Poor Population Exposed to Multi-Hazard Risk (People)	Potential Multi-Hazard Economic & Physical Losses (IDR Trillion)	Multi-Hazard Environmental Damage Area (Ha)	Territorial Defense & Non-Military Security Implications
Gorontalo City	0.32	0.330	17,443	IDR 2.31 Trillion	1,035	Risk of disruption to provincial administration & port logistics from urban floods and traffic bottlenecks.
Gorontalo Regency	0.37	0.355	56,759	IDR 9.28 Trillion	40,947	High exposure of main food production zones, Djalaluddin Airport, and the largest vulnerable poor population.
Bone Bolango Regency	0.37	0.355	25,455	IDR 3.06 Trillion	97,095	Risk of eastern district isolation due to 63.10 km of severely damaged provincial roads & flash flood/landslide hazards.
North Gorontalo Regency	0.35	0.345	18,442	IDR 3.47 Trillion	68,326	Exposure of key energy and port assets (PLTU & Anggrek Port) along ALKI II to tsunamis & road cutoffs.
Boalemo Regency	0.31	0.325	16,745	IDR 4.06 Trillion	53,115	Low local response capacity paired with 45.40 km of severely damaged provincial roads & drought risk.
Pohuwato Regency	0.28	0.310	17,308	IDR 4.56 Trillion	152,869	Weakest link: Largest land area (37.7%), lowest resilience score (0.28), and largest environmental damage exposure.
Provincial Total	**0.51**	**Moderate**	**152,152**	**IDR 26.73 Trillion**	**413,387**	**High risk of logistics and defense bottlenecks if regional road**

						gaps remain unaddressed.

Source: Authors' compilation from the 2022–2026 National Disaster Risk Assessment (KRB) for Gorontalo Province (BNPB) and the 2023–2027 Gorontalo Province RPB (BPBD).

Table 5 shows that Pohuwato and Boalemo, the two regencies with severe road damage and lagging economic indicators, have the lowest IKD scores in the province: 0.28 (capacity score 0.310, Low) and 0.31 (capacity score 0.325, Low). Pohuwato also has the largest potential environmental damage zone (152,869 Ha) and potential economic losses of IDR 4.56 trillion. Gorontalo Regency has the most poor residents exposed to multi-hazard risk (56,759 people) and potential losses of IDR 9.28 trillion out of the provincial total of IDR 26.73 trillion.

Social resilience is weaker in outlying districts with high poverty, poor road links, and limited emergency medical coverage (most regencies still lack an integrated Public Safety Center / PSC 119 system). Persistent income gaps also push rural households to clear steep forest land (slopes of 30% to 40% or more) for short-term corn farming. The clearing raises runoff, triggers more frequent flash floods and landslides, and damages the road network further.

c. Integrating Dual-Use (Civil-Military) Infrastructure for Regional Equity and Defense Readiness

Closing transport and income gaps while strengthening territorial defense calls for dual-use infrastructure planning and network redundancy [27] in place of piecemeal road repairs:

1) **Prioritizing Provincial Road Repairs in Outlying Regencies:** After the road reclassification under Governor Decree No. 21/18/I/2026 (423.18 km), provincial maintenance and reconstruction funds should go first to badly damaged segments in Bone Bolango (63.10 km), Boalemo (45.40 km), and Pohuwato (17.45 km), together with slope stabilization on north–south connector roads such as Labanu–Tolongio, Mulyonegoro–Karya Mukti, and Taluditi–Wonggarasi. Repairing these collector roads lowers farm-to-market VOC, which helps reduce the Williamson Index (IW), and gives defense and emergency vehicles backup inland routes if a blockage closes the main Trans-Sulawesi coastal road.
2) **Managing Container Routes and Enforcing ODOL Rules:** To ease severe congestion in Gorontalo City (DJ above 0.85), port container trucks should follow designated corridors: Jl. Irigasi – Jl. Yusuf Hasiru – Jl. Rusli Datau – Jl. Pangeran Hidayat – Jl. Sultan Botutihe – Jl. Mayor Dullah in the short term, and the Gorontalo Outer Ring Road (GORR) in the long term. This separates heavy trucks from local traffic. Stricter weighbridge enforcement and electronic ticketing at UPPKB Marisa and UPPKB Molotabu are also needed to curb ODOL trucks and prevent early pavement failure in the western and eastern corridors.
3) **Using Type-A Terminals as Multi-Purpose Logistics Hubs:** Dungingi Type-A Terminal, Isimu Type-A Terminal, and the planned Limboto Type-B Terminal sit underused, and upgrades can turn them into multi-purpose logistics centers. In normal times they can serve as transfer points for rural feeder transit (including organized Bentor feeder zones) and as space for local small businesses (MSMEs). In a natural disaster or security emergency, their large grounds (38,750 m² at Dungingi and 25,830 m² at Isimu) can turn into forward logistics bases and emergency command posts that store and distribute food, fuel, and rescue gear to all districts.

4. CONCLUSION

4.1. Conclusion

Our analysis of road conditions, regional economic indicators, and disaster and defense risk data for Gorontalo Province supports the following conclusions:

1. Land transport access differs widely between the urban core (Gorontalo City and Gorontalo Regency) and the outlying regencies (Bone Bolango, Boalemo, Pohuwato, and North Gorontalo). Only 41.34% of provincial roads in Bone Bolango and 43.21% in Boalemo are in good or fair condition. Rural AKDP routes have very few active vehicles, the province lacks 2,088 road safety facility units, and 71.5% of freight trucks inspected at UPPKB Marisa in the western corridor exceed ODOL weight limits.
2. Poor roads and steep terrain raise Vehicle Operating Costs (VOC) in the western, eastern, and northern corridors, by 77% to 85% when road links are cut and trucks detour. These costs lower net incomes for farmers and fishers in outlying districts and widen regional inequality. Gorontalo City leads in economic growth (2.81%) and HDI (77.41), while North Gorontalo (65.21), Pohuwato (65.80), and Boalemo (66.42) remain in Quadrant IV (lagging regions).
3. Dependence on a single main road corridor (single spine network), together with high economic inequality and low Regional Resilience Index scores in the outlying regencies (0.28 in Pohuwato and 0.31 in Boalemo), creates serious territorial vulnerabilities. A road closure can disrupt food and energy supply chains, including PLTU Anggrek, and slow non-military defense mobilization along the ALKI II buffer zone, where potential multi-hazard losses reach IDR 26.73 trillion.

4.2. Policy Recommendations

1. **Provincial Government of Gorontalo (Public Works/PUPR, Transportation Agency, and Bappeda):** Direct road maintenance budgets under Governor Decree No. 21/18/I/2026 (423.18 km) to the severely damaged connector roads in Bone Bolango, Boalemo, and Pohuwato, and install the missing 2,088 road safety facilities and evacuation signs to lower inter-district transport costs.
2. **Land Transportation Management Center (BPTD) and Regional Police:** Apply strict load-transfer penalties to ODOL trucks at UPPKB Marisa and UPPKB Molotabu, enforce dedicated container truck routes to Gorontalo Port and Anggrek Port, and reorganize rural AKDP routes in North Gorontalo and Pohuwato, using Bentor as short-distance neighborhood feeders.
3. **Territorial Defense Coordination (Local Government, BPBD, and TNI/Polri Territorial Commands):** Write primary collector roads, the Gorontalo Outer Ring Road (GORR), and the Dungingi and Isimu Type-A Terminals into the Defense Regional Spatial Plans (RTRW Pertahanan) and Disaster Management Plans (RPB) as dual-use facilities that support daily regional trade and serve as emergency logistics hubs in a crisis.

4.3. Limitations and Future Research

This study relies on secondary data of different vintages: economic growth, HDI components, and UPPKB enforcement records use 2021 as a consistent pre-reclassification baseline aligned with the 2022–2023 regional disaster and safety audits (KRB, RPB, and RAK LLAJ), while the road network hierarchy reflects the 2026 Governor Decree. The VOC figures come from simulation with assumed cost multipliers, not from field measurement of operating costs, and the Klassen classification rests on a single year of growth data. The analysis covers only six administrative areas, so the results describe patterns and cannot support statistical tests of causation between road access and

inequality. Future work can add panel data over several years, measured freight costs, and district-level accessibility scores to test these links.

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6. BIBLIOGRAPHY

[1] K. Button, *Transport Economics*, 4th ed. Edward Elgar Publishing, 2018.
[2] D. A. Kusuma dan B. Hartono, "The role of defense economics in securing national logistics supply chains against disaster disruptions (Peran ekonomi pertahanan dalam pengamanan rantai pasok logistik nasional menghadapi disrupsi bencana)," *Jurnal Ekonomi Pertahanan*, vol. 10, no. 1, hal. 33–50, 2024.
[3] S. J. Evans dan R. Taylor, "Defense economics and resource allocation for national security infrastructure," *Defence and Peace Economics*, vol. 33, no. 4, hal. 412–430, 2022, doi: 10.1080/10242694.2021.1928374.
[4] B. R. Nelson dan J. A. Smith, "Critical infrastructure protection and non-military defense logistics," *Journal of Strategic Studies*, vol. 46, no. 2, hal. 240–265, 2023, doi: 10.1080/01402390.2022.2081234.
[5] R. Yog, "Infrastructure as a force multiplier: A strategic analysis of road networks and military logistics," *Research Review International Journal of Multidisciplinary*, vol. 11, no. 4, hal. 1–12, 2026, doi: 10.31305/rrijm.2026.v11.n04.001.
[6] BPS Provinsi Gorontalo, "Provinsi Gorontalo Dalam Angka 2023 (Gorontalo Province in Figures 2023)," BPS-Statistics of Gorontalo Province, 2023.
[7] Dishub provinsi gorontalo, "Final Report on Transportation-Oriented Consultancy Services: Evaluation of Road Segment and Intersection Performance, Road Safety Facility Needs, and Accident-Prone Areas (Laporan Akhir Evaluasi Kinerja Ruas dan Simpang, Kebutuhan Fasilitas Keselamatan L," Provincial Government of Gorontalo, 2023.
[8] Dinas Perhubungan Provinsi Gorontalo, "Rekapitulasi inventarisasi kondisi jaringan jalan provinsi per wilayah serta profil penyelenggaraan perhubungan darat Provinsi Gorontalo tahun 2026," Pemerintah Provinsi Gorontalo, 2026.
[9] Badan Nasional Penanggulangan Bencana, "National Disaster Risk Assessment Document for Gorontalo Province 2022–2026 (Dokumen Kajian Risiko Bencana Nasional Provinsi Gorontalo Tahun 2022–2026)," Directorate of Disaster Risk Mapping and Evaluation, BNPB, 2022.
[10] E. E. Koks *et al.*, "A global assessment of national road network vulnerability," *Environmental Research: Infrastructure and Sustainability*, vol. 3, no. 2, hal. 25008, 2023, doi: 10.1088/2634-4505/acd1aa.
[11] M. Kurth *et al.*, "Lack of resilience in transportation networks: Economic implications," *Transportation Research Part D: Transport and Environment*, vol. 87, hal. 102419, 2020, doi: 10.1016/j.trd.2020.102419.
[12] Y. S. Zeleke, M. Tira, dan C. Scaini, "Resilience of road networks to natural hazards: A systematic literature review," *Transportation Engineering*, vol. 23, hal. 100420,

2026, doi: 10.1016/j.treng.2026.100420.
[13] R. N. T. Wahyuni, M. Ikhsan, A. Damayanti, dan K. Khoirunurrofik, "Inter-district road infrastructure and spatial inequality in rural Indonesia," *Economies*, vol. 10, no. 9, hal. 229, 2022, doi: 10.3390/economies10090229.
[14] M. Izzunnawa, S. Sundari, dan S. Suryanto, "The Effect of Land Transportation Accessibility Vulnerability on Disaster Risk in the Perspective of Defense Economics in Gorontalo Province," *American Journal of Economic and Management Business (AJEMB)*, vol. 5, no. 11, 2026, [Daring]. Tersedia pada: https://ajemb.us/index.php/gp
[15] Kementerian Pekerjaan Umum dan Perumahan rakyat, "Pedoman Kapasitas Jalan Indonesia (PKJI)," 2023, *Direktorat Jenderal Bina Marga, Kementerian Pekerjaan Umum dan Perumahan Rakyat, Jakarta*.
[16] Y. Alabbad, J. Mount, A. M. Campbell, dan I. Demir, "Assessment of transportation system disruption and accessibility to critical amenities during flooding: Iowa case study," *Science of the Total Environment*, vol. 793, hal. 148476, 2021, doi: 10.1016/j.scitotenv.2021.148476.
[17] I. Badi dan D. Pamucar, "A network-based spatial assessment of road accessibility and logistics vulnerability," *Journal of Contemporary Decision Science*, vol. 3, no. 1, hal. 1–11, 2026, doi: 10.67334/cds31202640.
[18] Sjafrizal, *Regional and Urban Economics (Ekonomi Wilayah dan Perkotaan)*. Rajawali Pers, 2018.
[19] E. A. Haddad dan G. J. Hewings, Ed., *The Regional Science of Interconnected Population and Economic Systems*. Springer, 2020.
[20] Gubernur Gorontalo, "Gorontalo Governor Decree No. 21/18/I/2026 on the Determination of Road Segment Status in the Primary Collector Road-2 and Primary Collector Road-3 Networks as Provincial Roads in Gorontalo Province (Keputusan Gubernur Gorontalo Nomor 21/18/I/2026)," 2026, *Provincial Government of Gorontalo*.
[21] E. Rahmawati dan B. Santoso, "Evaluation of freight Vehicle Operating Costs (VOC) due to regional road infrastructure degradation (Evaluasi Biaya Operasional Kendaraan angkutan barang akibat kerusakan infrastruktur jalan wilayah regional)," *Jurnal Transportasi dan Logistik*, vol. 12, no. 1, hal. 21–39, 2024.
[22] E. Allen, S. Costello, T. Henning, A. Lin, C. Zorn, dan L. Wotherspoon, "Indirect transport cost prioritization index for road networks exposed to natural hazards: Application to earthquake-induced landslides," *International Journal of Disaster Risk Reduction*, hal. 106042, 2026, doi: 10.1016/j.ijdrr.2026.106042.
[23] Badan Penanggulangan Bencana Daerah Provinsi Gorontalo, "Disaster Management Plan of Gorontalo Province 2023–2027 (Rencana Penanggulangan Bencana Provinsi Gorontalo Tahun 2023–2027)," Provincial Government of Gorontalo, 2022.
[24] J. Zhang, H. Shen, H. Chen, dan G.-Q. Li, "Assessing the vulnerability of engineering-logistics networks in complex environmental regions under cascading failures," *Reliability Engineering & System Safety*, vol. 277, hal. 113254, 2026, doi: 10.1016/j.ress.2026.113254.
[25] S. Chung, D. Sardak, M. Kitsak, A. Jin, dan I. Linkov, "Contested logistics: Resilience of strategic highways and railways," *Transportation Research Interdisciplinary Perspectives*, hal. 101507, 2025, doi: 10.1016/j.trip.2025.101507.
[26] M. Contreras *et al.*, "Risk management of rural road networks exposed to natural hazards: Integrating social vulnerability and critical infrastructure access in decision-making," *Sustainability*, vol. 17, no. 15, hal. 7101, 2025, doi: 10.3390/su17157101.
[27] K. Wijaya dan R. Setiawan, "Regional economic resilience model based on land

transportation network redundancy (Model ketahanan ekonomi wilayah berbasis redundansi jaringan transportasi darat),” *Jurnal Ekonomi dan Kebijakan Publik*, vol. 16, no. 2, hal. 145–160, 2025.