Operational Efficiency and Headway Optimization of Commuter Paratransit Routes: A Case Study of the Kota-Isimu Corridor

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Abstract: The Kota–Isimu corridor serves as the high-density commuter spine of Gorontalo Province, capturing the largest public transport market share. However, individualistic paratransit operations (AKDP) along this route suffer from severe operational inefficiencies due to uncoordinated dispatching and destructive competition. This study evaluates the micro-operational performance of the Kota–Isimu corridor and proposes a regulated headway optimization model. Empirical field data were collected through synchronized passenger on-board counts and static roadside screenline surveys. The results reveal that while the corridor handles a peak daily demand of 100 passengers, the over-allocation o f 37 active fleets generates an excessive daily supply of 222 seats. This over-saturation drops the mean route headway to 8.5 minutes, resulting in a critically low average Load Factor of 28%. To eliminate empty-running and curbside passenger poaching, we model a scheduled headway expansion. The optimization framework demonstrates that restructuring the off-peak headway from 8.5 minutes to a stabilized 15-minute interval effectively consolidates passenger volumes, raising the individual vehicle Load Factor above the 50% economic break-even threshold without causing excessive passenger waiting times. This study provides a practical blueprint for transitioning from fragmented supply-driven paratransit to regulated, efficient commuter corridors in developing regions.

Keywords: *Commuter Paratransit; Headway Optimization; Load Factor; Operational Efficiency; Kota–Isimu Corridor.*

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I. INTRODUCTION

In developing secondary cities, commuter corridors connecting urban cores to regional transit growth centers are heavily dependent on informal or semi-formal paratransit networks [1,5]. These systems offer highly flexible and adaptive transport services. However, when multiple individual owner-operators compete directly on the same high-demand corridor without centralized scheduling, the transit market inevitably descends into destructive competition [4]. Operators rush to capture passengers during limited peak intervals, leading to highly volatile vehicle headways, severe asset underutilization, and compromised road safety [3].

In Gorontalo Province, Indonesia, the corridor linking Gorontalo City to Isimu (Route 1) represents the primary spine of regional commuter mobility [2]. It channels daily movements of workers, students, and traders moving between the provincial capital and the gateway node of Isimu. Despite its strategic importance, the route is characterized by low operational efficiency. The proliferation of private motorized vehicles and online ride-hailing alternatives has eroded the public transit passenger base. Yet, the active paratransit fleet count remains highly bloated due to an outdated, permit-allocation regulatory framework that treats transit supply as static.

While macro-level studies frequently address regional demand-supply mismatches [2], there is a critical need for micro-level operational diagnoses that target high-frequency corridors [3]. Most existing paratransit optimization models assume institutionalized fleet management, which is absent in non-metropolitan Indonesian provinces. This study directly addresses this gap by analyzing the empirical operations of the Kota–Isimu corridor. The primary objective of this paper is to quantify the exact operational inefficiencies of Route 1 using high-resolution field tracking of headways and load factors, and subsequently formulate a mathematically viable headway optimization framework to secure the economic and service sustainability of the corridor.

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II. METHODOLOGY

➢ *Corridor Profile and Field Observation*

The spatial scope of this investigation is strictly confined to Route 1 (Kota Gorontalo – Isimu corridor), which measures approximately 22 kilometers. This route features the highest concentration of active paratransit vehicles (AKDP microbuses) in the province, with 37 registered units operating daily [2]. Field observations were executed simultaneously using a combination of dynamic on-board passenger counts and static screenline headway tracking over a multi-day window to capture distinct temporal variations.

➢ *Optimization Modeling Framework*

To evaluate and restructure vehicle intervals, the empirical headway (H_i) was derived from the passing timestamps (ti) at the screenline boundary:

$$H_i = t_i - t_{i-1}$$

The operational efficiency was benchmarked using the vehicle Load Factor (*LF*), calculated as:

$$LF = \frac{P_{max}}{C} x100\%$$

Where P_{max} is the peak on-board passenger count per run and C is the vehicle seating capacity (C = 6 seats available per simulated vehicle run based on active capacity divisions).

The headway optimization model seeks to find an optimal headway (H_{opt}) that maximizes the vehicle Load Factor toward an economically viable target ($LF_{target} \geq 50\%$) while minimizing the total passenger waiting time (Wp) [3]. The optimization constraint is formulated as follows:

$$H_{opt} = \frac{60xCxLF_{target}}{q}$$

Where q represents the dynamic passenger arrival rate (passengers/hour) derived from the empirical demand profiles across the temporal observation windows.

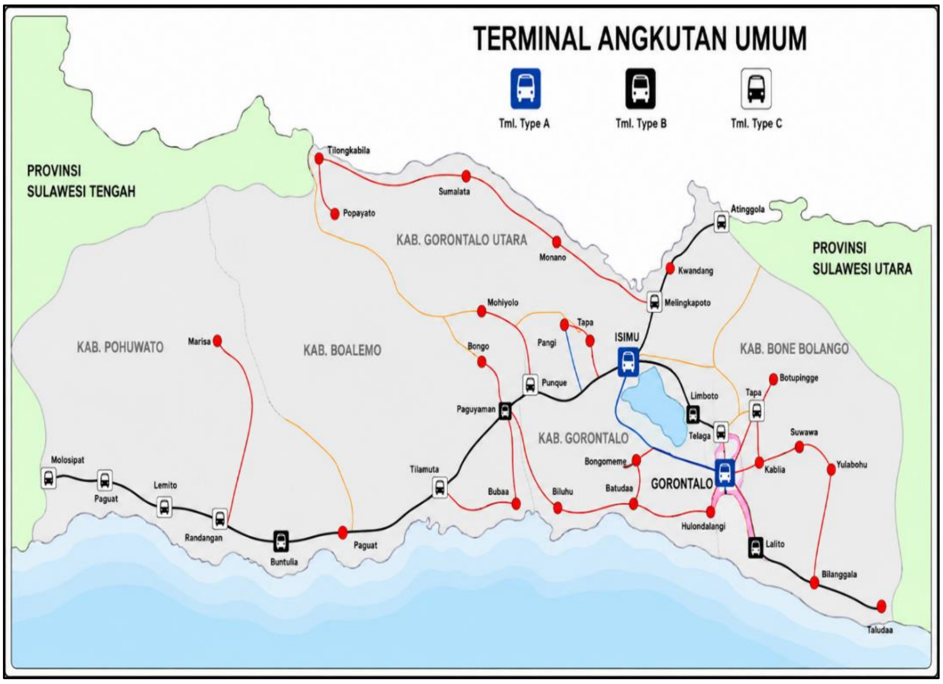

Fig 1 Geographic Layout and Spatial Distribution of the Five Intercity Paratransit (AKDP) Corridors in Gorontalo Province

III. RESULTS AND DISCUSSION

➢ *Micro-Operational Diagnosis: Saturated Supply and Low Utilization*

The empirical tracking of Route 1 demonstrates a deep operational deficit [2]. The corridor operates with an active fleet of 37 vehicles per day, generating a total daily seat supply (S_1) of 222 seats. However, the actual cumulative passenger demand (D_1) recorded throughout the tracking window was exactly 100 passengers per day [2].

This extreme imbalance results in an average operational Load Factor (*LF*) of just 28%. Because the total supply capacity significantly exceeds the passenger volume, vehicles are consistently running nearly empty. Operators compete aggressively on the asphalt to capture any available roadside passengers, which leads to erratic, uncoordinated headways that average a tight 8.5 minutes [2].

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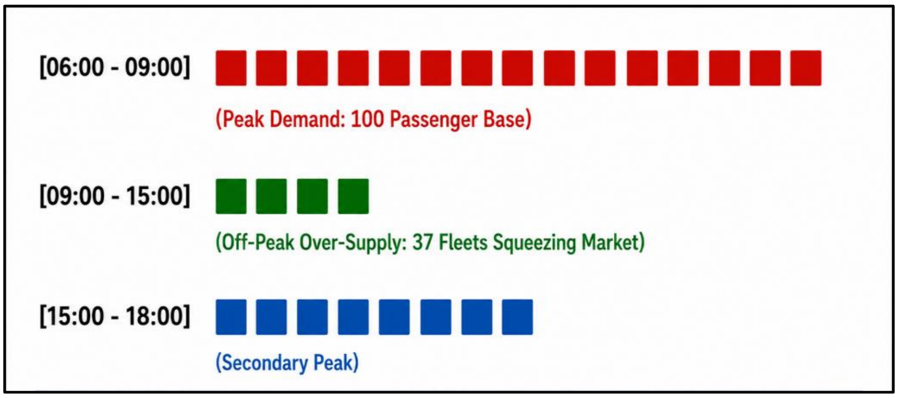

Fig 2 Temporal Demand Compression vs. Fixed Fleet Allocation on Route 1

➢ *Headway Volatility and Curbside Behavior*

The tight average headway of 8.5 minutes does not translate into high-quality service reliability [3]. Field tracking reveals extreme headway variance: during peak commuter hours (06:00–09:00), multiple vehicles dispatch sequentially within 2 to 3 minutes of each other as drivers attempt to poach passengers from their immediate competitors [4,5]. During off-peak intervals (09:00–15:00), this destructive behavior shifts to prolonged terminal waiting times or excessive crawling speeds along the highway. This creates artificial delays, increases passenger frustration, and accelerates transit abandonment in favor of private motorcycles.

➢ *Headway Optimization and Restructuring Simulation*

To resolve this structural deficit, a scheduled headway optimization simulation was applied to the empirical passenger arrival rate (q) during off-peak windows [3]. By expanding and enforcing the vehicle dispatch intervals, the system can systematically consolidate passenger demand per vehicle run.

Table 1 Operational Simulation: Empirical vs. Optimized Headway

Operational Metric	Empirical Framework (Current)	Optimized Framework (Proposed)	Structural Impact
Active Fleet Volume (Veh/Day)	37	20	Fleet reduction of 45.9%
Mean Vehicle Headway (Minutes)	8.5	15.0	Balanced time interval
Hourly Service Frequency (Veh/Hour)	7.05	4.00	Reduced unutilized road supply
Average Load Factor ($LF\%$)	28%	52%	Exceeds economic break-even

To break this vicious cycle, Gorontalo Province must transition from a fragmented, supply-driven individual operator framework toward a consolidated, headway-regulated transit management system [1], [4].

IV. CONCLUSION AND POLICY RECOMMENDATIONS

➢ *Conclusion*

The Kota–Isimu corridor suffers from severe economic and operational inefficiencies driven by an over-allocation of active fleets relative to actual passenger demand [2]. The presence of 37 uncoordinated vehicles driving a low 28% load factor proves that a supply-driven, unregulated paratransit model cannot sustain commuter mobility [4].

➢ *Policy Recommendations*

To salvage the economic viability of this vital spine, the provincial transport authority must enforce a fixed 15-minute dispatch headway during off-peak intervals [3]. This operational adjustment must be legally supported by integrating independent drivers into a single corridor cooperative framework, transitioning the route's economic model from predatory passenger chasing to centralized, reliable service delivery [1], [4].

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