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Optimization Model for Land Use Intensity Control Based on Building Floor Coefficient and Road Performance in Urban Transportation (Case Study Main Corridor of Parepare City)

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Abstract: The functional relationship between the intensity of spatial use floor area ratio (FAR) and road network performance is fundamental in the context of rapid urban development. This study aims to quantify and model the spatial relationship between the actual FAR, deterioration of road performance—degree of saturation (DS) and side barriers (HS), on the main road corridor of Parepare City, using a deductive quantitative approach. The analysis begins with the collection of FAR and DS data referring to Indonesian road performance guidelines (PKJI, 2023), followed by the estimation of a Spatial lag regression model (SLM) to internalize the dimensions of spatial dependence. SLM model shows strong explanatory power (R^2 = 0.78), empirically confirming a positive and significant correlation between improvement FAR and DS. A key finding is the validation of a significant positive spatial autocorrelation (ρ = +0.387, $p < 0.01$), which proves that congestion is the result of spillover effects between connected segments, not an isolated phenomenon. These results justify that traffic interventions should be network-based. Furthermore, this study applies predicted scenarios of FAR increase (+10%, +20%, and maximum zoning limit 4.0). The results of this scenario are crucial, increasing FAR to the maximum zoning limit drastically predicts total functional failure in most segments (predicted to reach LOS E and F), especially in residential zones that show the highest FAR sensitivity ($\beta_{FARtotal}$ = +0.200). The main contribution of this study is to provide an adaptive model to determine FAR based on a critical performance threshold (DS_{max} = 0.75). Policy implications recommend a holistic integration between spatial planning and transportation regulations, demanding an immediate revision of the maximum FAR limit (as mandated on the priority map) to a sustainable FAR, as well as the implementation of network-based mitigation strategies, rather than point-based, to manage the urban mobility crisis sustainably.

Keywords: Floor area ratio; Road performance; Degree of saturation; Level of service; Transportation system; Spatial regression

1 Introduction

Accelerated urban population growth has triggered a surge in demand for transportation services, which has now become a fundamental challenge in regional planning [1]. Sustainable urbanization requires integration between transportation needs and land use to create economic balance, environmental stability, and social equity [1]. Essentially, transportation is a system for moving objects between locations that forms a vital connectivity network for development [2]. The interaction between land use patterns and modes of transportation significantly affects traffic movement intensity, which in turn dictates infrastructure capacity requirements [2, 3].

In mitigating these problems, the implementation of regional zoning and land use regulations integrated with traffic control are crucial instruments for harmonizing infrastructure development with population spatial patterns [4]. Mixed land use strategies are recommended to improve urban mobility through reduced travel distances and optimized road performance [5]. The feedback dynamics between population density and land use structure directly affect travel behavior and transportation system efficiency [5].

The paradigm shift from the classical approach to the compact city concept offers planning solutions that are oriented towards long-term sustainability and economic efficiency. Research shows that urban vitality is determined more by the level of service (LOS) than by physical road capacity alone [6]. In densely populated areas, traffic congestion linearly reduces the effective capacity and service quality of infrastructure [7].

Optimizing LOS requires a synchronized spatial utilization control model, involving parameters such as Building Coverage Ratio (BCR) and Floor Area Ratio (FAR) [8]. Imbalances between building permits and infrastructure capacity often trigger systemic congestion [9]. The use of genetic algorithms and system dynamics in transportation mode integration has been proven to significantly reduce congestion indices [10]. In addition, control instruments such as zoning and incentives are essential to maintain spatial order, given that changes in mobility have a direct impact on property values and land use patterns [11, 12].

Empirical studies show that spatial heterogeneity contributes positively to the service level index, while area homogeneity tends to be neutral [13]. In Indonesia, the complexity between the variables of accessibility, traffic capacity, and land configuration are determining factors in regional development acceleration [14]. Limited accessibility, as identified in PALI Regency, has an impact on regional economic growth stagnation [15]. Therefore, effective urban planning must consider transportation network designs that are responsive to land use characteristics [16].

This study is in line with a previous study in Makassar that emphasized adjusting building intensity to improve road performance [17]. Previous findings confirm that unregulated commercial land use can cause traffic loads to exceed road capacity by up to 43% [18]. As a solution, urban consolidation is directed at areas that are already served by public transportation [19]. This approach adopts a mobility and capacity-based integration model to create a sustainable urban environment and comprehensively address congestion issues.

In Parepare City, the intensity of space utilization is largely determined by the carrying capacity of the land itself. Historically, increased traffic volume has had an impact on travel time, so road network optimization has focused on strengthening the origin-destination (OD) demand multiplier. This analysis uses the Indonesian Road Capacity Guidelines (PKJI) methodology to evaluate the maximum traffic load limit without exceeding the road service level threshold.

This study offers advantages through a holistic, multidimensional approach. Although previous studies have confirmed that road vitality is influenced by construction intensity and building functional diversity, the synergistic interaction between road capacity and building density has not been explored in depth. In fact, understanding the threshold of building function effects is crucial to maintaining the balance of urban space vitality [19].

As a solution to urban transportation problems, this study analyzes FAR scenarios on the main road corridor of Parepare City. The decline in road capacity due to side obstacles and inadequate geometric design requires a land use model that can integrate FAR values with road service quality. This is important considering that the study results show that certain road segments in Parepare have reached LOS categories D to E, which characterize high density and low speed [20].

The imbalance between infrastructure availability and the surge in mobility demand has caused the LOS index to become unstable. Therefore, this study aims to develop an optimization model for controlling land use intensity using spatial regression analysis scenarios based on road performance and FAR parameters. This study is expected to contribute to the literature on land use models and sustainable micro-transportation systems in the context of urban transformation in Indonesia.

2 Material and Methods

This study applies a deductive quantitative approach to model the spatial relationship between land use intensity represented by GIS survey-based FAR and road network performance measured through degree of saturation (DS). Through the integration of primary data from semi-mechanical traffic surveys and road geometric variables in the main corridors of Parepare City, this study uses spatial regression analysis (spatial lag or spatial error) to produce unbiased regression coefficients (β). This approach aims to quantify the direct impact of FAR on DS and identify spatial autocorrelation coefficients (ρ or λ) as a representation of spillover effects between road segments, which is a novelty in formulating the functional relationship between spatial control and urban transportation dynamics.

2.1 Research Approach

This study uses a deductive quantitative method that focuses on spatial correlation analysis to test the hypothesis regarding the significant effect of vertical space utilization intensity FAR on road operational performance parameters DS. The analytical framework integrates GIS-based field data to calculate FAR in planning zones with geometric data and side obstacles to evaluate DS values based on road capacity. To ensure the accuracy of statistical inference, this study applies spatial regression modeling (Spatial Lag or Spatial Error Model) if autocorrelation is detected through Moran's I test. This approach is specifically designed to eliminate bias due to the spillover effect of traffic, thereby enabling the precise quantification of the impact of development intensity policies on the level of road network service in Parepare City.

2.2 Data Collection

Data collection was conducted through structured primary surveys in the main corridors of Parepare City to meet the needs of spatial econometric modeling. FAR data was obtained through synoptic physical inventory of land and buildings, which was then validated using a Geographic Information System (GIS) to produce average FAR values per planning zone. Simultaneously, road performance data was collected through semi-mechanical traffic surveys at representative observation points that met geometric elimination criteria to minimize flow distortion. Supporting variables such as road geometry and side obstacles were identified to calculate road capacity according to operational parameters, thereby producing valid and reliable data for analyzing the functional relationship between land use policies and road service levels.

2.3 Data Analysis Method

2.3.1 Analisis spasial pada floor area ratio

The FAR analysis model serves as a regulatory instrument to control development density and ensure infrastructure availability by setting building volume thresholds in specific zones. Although FAR is conventionally determined based on zoning classifications such as high-density commercial or residential areas this analysis expands the framework by integrating road infrastructure carrying capacity through precise mathematical calculations. By positioning FAR as a determining variable, this model is able to identify transportation movement patterns through a comprehensive evaluation of spatial distribution and land use characteristics, thereby enabling accurate trip rate estimates based on the differentiation of area functions along the observation corridor.

2.3.2 Road performance service level ratio analysis

Road performance analysis integrates vehicle movement intensity which is triggered by land use patterns with infrastructure carrying capacity based on the Indonesian Road Capacity Guidelines (PKJI) methodology [21]. Urban road capacity (C) is calculated by adjusting the base capacity (C0) for factors such as lane width, directional dividers, side obstacles, and city size, particularly on road segments with flat gradients and straight alignments. The quality of road operational performance is further quantified through the DS, which is the ratio of traffic volume to capacity, representing the level of density and stability of vehicle flow. The use of passenger car units (PCU) as the basis for calculating volume enables precise estimation of travel speed (VMP) and travel time (WT), which ultimately determines the Volume to Capacity Ratio (VCR) index as the main parameter in evaluating road service levels.

2.3.3 Spatial regression analysis and model scenarios

The spatial regression analysis framework is used to test the causal relationship between the FAR and DS variables by addressing violations of the assumption of independence of observations through the detection of spatial autocorrelation. The procedure begins with Moran's I test to identify patterns of geographical dependence, followed by model selection through the Lagrange Multiplier (LM) test to choose between the spatial lag model (SLM) to capture the spillover effect of the dependent variable or the Spatial Error Model (SEM) to correct for bias in auto correlated errors. The construction of a spatial weighting matrix (W), based on either contiguity or inverse distance, is a crucial instrument for defining connectivity between analysis units. Data integration through GeoDa software allows the separation of the direct impact of the FAR policy (β) from spatial influences (ρ or λ), resulting in comprehensive and responsive spatial planning policy recommendations that address the dynamics of cross-zone traffic loads.

3 Result and Discussion

3.1 Location and Characteristics of the Research Area

The city of Parepare, strategically located on the southwest coast of South Sulawesi, is often referred to as the "port city" or "gateway to Eastern Indonesia after Makassar." This position gives the city its distinctive urban characteristics, which have been analyzed through several urban theory lenses. Parepare City, as a port center, has historically and contemporarily functioned as a distribution hub for goods and services, not only for the Parepare City area itself but also for the inland regions of South Sulawesi (Ajatappareng: Barru, Pangkep, Enrekang, Sidrap, Pinrang, and Wajo), can be seen on the research area map, in Figure 1.

Compliance with the Spatial Plan from the results of a comparative analysis between existing land use intensity patterns and the provisions set out in the Parepare City Spatial Plan (RTRW) Parepare City Regulation on RTRW [22], identifies the level of compliance with the plan. The discrepancy between the intensity of development in the field and the zoning and building floor coefficient restrictions that have been set may indicate problems in controlling spatial utilization and the need for more effective law enforcement.

The spatial distribution of building intensity based on the results of spatial analysis of the approved FAR in building permits reveals a higher concentration of building intensity in the city center and along the main arterial road corridors. This pattern reflects the dominant commercial and service functions in these areas, which tend to require buildings with larger floor areas relative to land area. Conversely, low-density residential areas on the outskirts of the city generally show lower building FAR values.

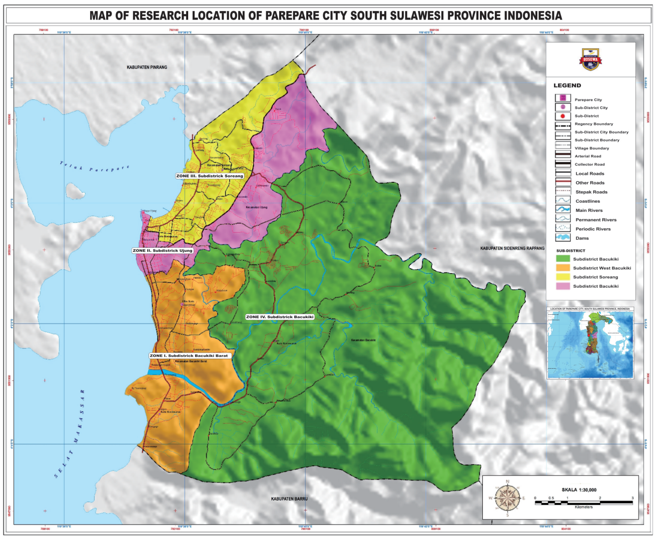


Figure 1. Map of the research location in Parepare City

3.2 Land Use Intensity Building Floor Coefficient Land use Intensity

Analysis of the actual FAR in the main corridor of Parepare City provides critical quantitative parameters for evaluating the physical density and intensity of existing space utilization. Through the calculation of gross floor area relative to total land area, significant variations in BCF values were identified, ranging from 0.2 in peripheral areas to 1.3 in dense commercial zones such as Jalan Bau Massepe, can be seen in Figure 2. These findings serve as vital indicators for determining the development potential of the area and evaluating the alignment of development with the Regional Spatial Plan (RTRW) or Detailed Spatial Plan (RDTR) documents. This data forms the basis for critical evaluation of environmental carrying capacity and road network performance, can be seen in Table 1. While also providing a foundation for the formulation of spatial policies that are adaptive to the dynamics of urbanization in order to mitigate future land use incompatibilities.

3.3 Geometry, Traffic Volume, and Capacity

Table 1. Recapitulation of building floor coefficients for the zone area

Main Corridor Roadside Area	Building Floor Coefficient Actual
Zone area I subdistrict Bacukiki Barat	
Mattiro Tasi Road	0.5
Bau Massepe Road	1.3
Agussalaim Road	0.9
Jend. Sudirman Road	0.4
Zone area II subdistrict Ujung	
Karaeng Burane Road	0.9
Jend. Ahmad Yani Road	0.6
Zone area III subdistrict Sqreang	
Andi Arsyad Road	1.0
Lahalede Road	0.8
Zone area IV subdistrict Bacukiki	
Lingkar Kota Parepare Road	0.2
Jend Muh. Yusuf Road	0.3

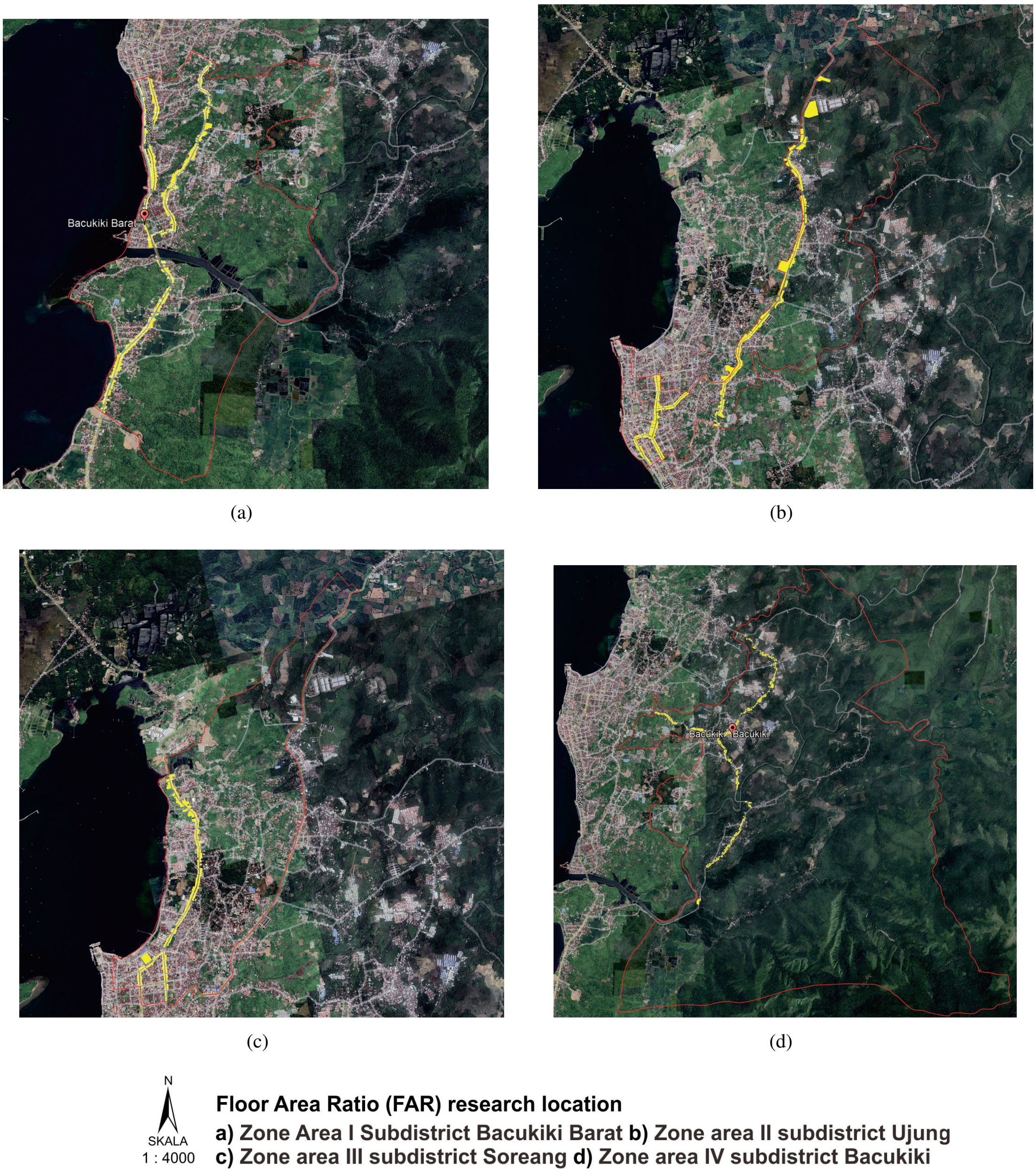


Figure 2. Building floor coefficient data along the corridor of each zone in the area

Geometric data of road cross-sections in the study area is a fundamental parameter in determining the adjustment factor for road performance analysis. Visual observations show variations in lane width, the presence of medians, and shoulders on arterial and collector roads, which are influenced by the diversity of land use activities in the surrounding area. Based on these characteristics, road capacity calculations are performed according to road typology, where undivided roads (2/2-TT) are analyzed using total two-way volume, while divided roads (4/2-T, 6/2-T, and 8/2-T) are evaluated separately per lane and direction. The results of this capacity analysis integrate all physical and geometric variables of the roads in the four main corridor zones of Parepare City to produce accurate estimates of infrastructure capacity can be seen in Table 2.

Traffic volume analysis in the main corridors of Parepare City provides a quantitative representation of road load and vehicle movement intensity through data collection at specific time intervals. The data is processed to identify peak periods and calculate the Average Daily Traffic (ADT), which serves as a fundamental parameter in evaluating the typical load characteristics of each road segment. The results of this analysis, as presented in Figure 3, Figure 4, and Table 3, form a crucial basis for measuring the effectiveness of vehicle flow distribution in relation to available infrastructure capacity.

The results of quantitative analysis through a 24-hour simultaneous survey on ten road segments in four strategic zones of Parepare City show significant fluctuations in functional load, with the highest volume peak identified in the main corridor of Zone I, West Bacukiki District. This validated volume data became the primary input in computing the actual capacity (C), which was obtained by calibrating the Base Capacity (C0) using a series of technical correction factors in accordance with PKJI guidelines, including lane width (FCLJ), directional separators (FCPA), city size (FCUK), and side obstacles (FCHS). The integration of these volume and capacity parameters produces accurate DS values, as presented in Tables 3 and 4, to evaluate daily mobility dynamics and the operational performance of the road network in the study area.

The analysis of HS on all segments reached a cumulative value of 3546.5, with the highest intensity identified in Segment 2 (Zone I) and Segment 8 (Zone III), which were dominated by parking/stopping vehicle (PSV) activities and vehicle entry-exit (EEV) flows. Based on the SLM regression coefficient, which shows a significant positive correlation (ρ_{HS} = +0.006), policy interventions should focus on radical side obstacle management through a moratorium on roadside parking and tighter access regulations to increase effective capacity (C). Although the highest capacity was recorded on the main corridor of Zone I (Bacukiki Barat Subdistrict), HS control remains crucial to reduce the DS and maintain the stability of the LOS, as presented in Tables 3 and 5.

Analysis of speed and travel time confirms that mobility effectiveness in the main corridor of Parepare City is currently still in the ideal category with stable flow, where the operational speed value is close to the free-flow speed (VMP). Based on the LOS classification categories A to C, infrastructure performance in Zones I and II is still considered optimal, but indications of declining efficiency have begun to be identified in specific segments as traffic volume increases. These findings reveal a significant correlation between the intensity of space utilization represented by the actual FAR value of 0.2–1.3 and road service performance, as summarized in Table 6, Table 7, and Figure 4.

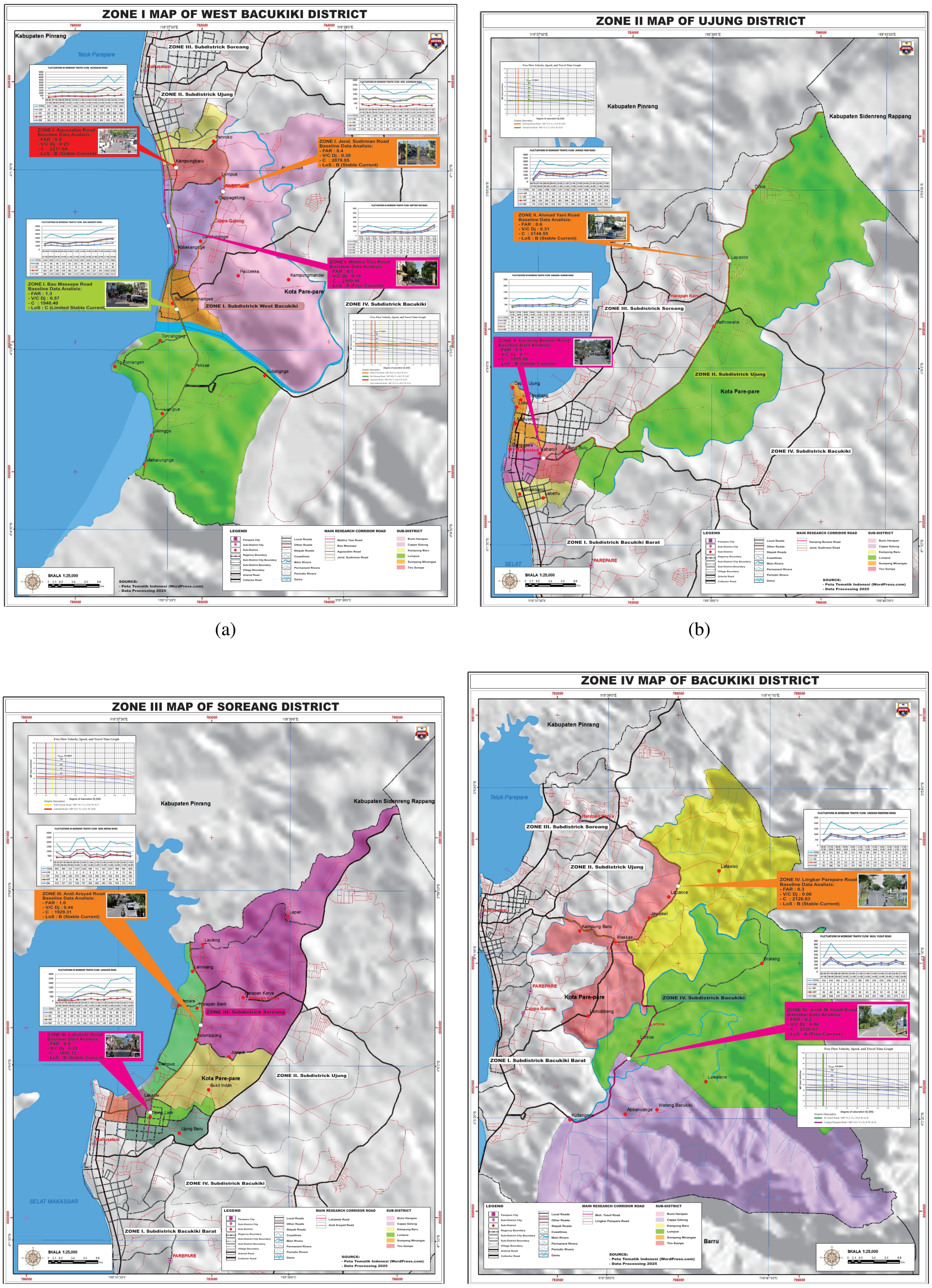
Table 2. Results of analysis of road segment conditions

No.	**Description**	**Area Zoning Road Infrastructure Specifications**		
		Zone. I, II, III, IV	**Zone. I, II, III**	**Zone. II, III**
		2/2-TT	4/2-T	1/1
1	Traffic lane width (m)	7.0		
2	Effective shoulder width on both sides (m)	1.5	4×3.5	2×3.5
3	Closest distance from curb to barrier (m)	-	2.0	2.0
4	Median	-	Yes, no opening	-
5	Direction divider (%)	50–50	50–50	50–50
6	KHS	Low	Low	Low
7	City size (millions of inhabitants)	<1.0–3.0	<1.0–3.0	<1.0–3.0
8	Alignment type	Flat/Hilly	Flat/Hilly	Flat/Hilly
9	Composition of MP: KS: SM	60%: 8%: 32%	60%: 8%: 32%	60%: 8%: 32%
10	K-factor	0.08	0.08	0.08

3.4 Spatial Regression and Model Scenarios

The validity test using Moran's I index on OLS residuals shows a significant positive value (I = 0.42; $p <$ 0.01), confirming the existence of positive spatial autocorrelation where road performance characteristics DS in Parepare City tend to cluster non-randomly. This finding validates the use of the SLM, which produces a high level of conformity (R^2 = 0.78) and a spatial autoregressive coefficient (ρ) of +0.387 ($p <$ 0.01). The results reveal a significant spillover effect, where a decline in performance in one segment such as on Jalan Bau Massepe with the highest FAR value of 1.5 contributes 38.7% to the increase in DS in the surrounding segments through network effects, as presented in Table 8 and Figure 5.

Analysis of model validity through SLM estimation in each functional category confirms the existence of spatial heterogeneity in the relationship between development intensity and road performance. The validity of the FAR coefficient shows significant sensitivity variation, with the highest impact found in the office zone (β_{FAR} = +0.200) and the lowest in the residential zone (β_{FAR} = +0.130). In addition, the higher spillover parameter (ρ) in the office area (ρ = 0.390) reflects a more rigid network connectivity, thereby accelerating the transmission of congestion between segments. These findings consistently confirm that policies to control spatial intensity in the Parepare corridor must be zone-specific, taking into account the sensitivity coefficients and unique spatial dynamics of each area function, as presented in Table 9.



(a) (b) (c) (d)

Figure 3. Map of zones and road segments along with graphs of vehicle volume, speed, and travel time

The interaction coefficient analysis shows that the impact of an increase in FAR on the DS in the Office Zone is much more significant (β_{total} = 0.200) than in the main commercial zone (β_1 = 0.150). In addition, the differential intercept finding (γ_2 = +0.120) indicates that the office zone has a higher baseline DS load due to latent factors such as peak hour traffic concentration and suboptimal internal circulation management. This model also confirms the crucial role of side barriers (β_{HS} = +0.006) in worsening road performance degradation, in contrast to the capacity variable (β_C = -0.0001), which consistently reduces DS values. Therefore, policy interventions in Parepare City require cross-sectoral coordination that integrates building intensity control with side barrier management to ensure the sustainability of road network performance, as detailed in Table 10.

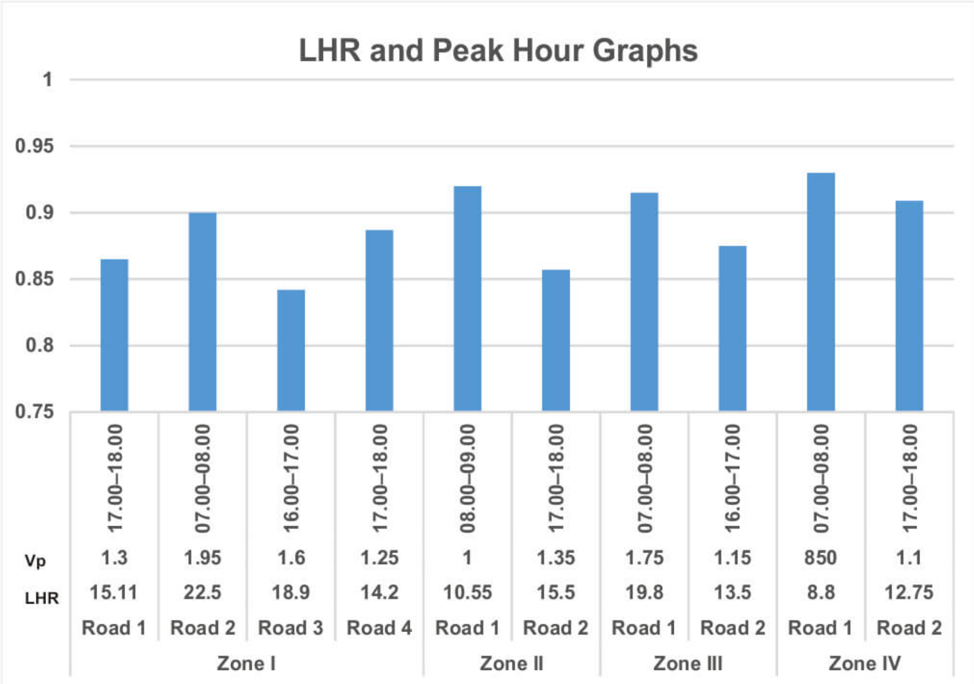


Figure 4. Graph of vehicle volume based on observation time

Table 3. Capacity value and adjustment correction factor

Main Corridor Road Zone	Capacity Value and Adjustment Correction Factor (smp/h)					
	C_0	FC_{LJ}	FC_{PA}	FC_{HS}	FC_{UK}	C
Zone area I subdistrict Bacukiki Barat						
Mattiro Tasi Road	3400	0.92	1	0.92	0.90	2589.98
Bau Massepe Road	2800	1	1	0.77	0.90	1940.40
Agussalaim Road	2800	1	1	0.88	0.90	2217.60
Jend. Sudirman Road	3400	0.96	1	0.98	0.90	2878.85
Zone area II subdistrict Ujung						
Karaeng Burane Road	2800	0.87	1	0.91	0.90	1995.08
Jend. Ahmad Yani Road	2800	0.87	1	0.98	0.90	2148.55
Zone area III subdistrict Soreang						
Andi Arsyad Road	2800	0.87	1	0.88	0.90	1929.31
Lahalede Road	2800	0.87	1	0.90	0.77	1688.15
Zone area IV subdistrict Bacukiki						
Lingkar Kota Parepare Road	2800	0.87	1	0.97	0.90	2126.63
Jend Muh. Yusuf Road	2800	0.87	1	0.99	0.90	2170.48

Spatial regression analysis confirms that the intensity of development in Parepare City is the main determinant of road performance degradation, with a β_{FAR} coefficient of +0.184, indicating that each one-unit increase in FAR will increase the DS linearly by 0.184. In addition to this local impact, a highly significant spillover effect (ρ = +0.387) was found, indicating that an increase in traffic density in one segment will be distributed and burden other segments along the main corridor. Through the "Do Something" simulation scenario, which tests FAR incrementality of 10% to 20%, DS change predictions are calculated using the SLM structural coefficient to mitigate the risk of a decline in the LOS according to PKJI standards. These findings confirm that road capacity improvement policies must be integrated with HS control and strict FAR regulations to prevent systemic congestion transmission throughout the urban network.

Table 4. Total vehicle volume for all road corridors in each zone of the area

Main Corridor Road Zone	Total Traffic Volume Vehicles/Hour km/h (q)	Traffic Volume in Vehicles smp/h (q)
	Zone area I	
Mattiro Tasi Road	1246.30	478.80
Bau Massepe Road	1978.83	1101.03
Agussalaim Road	1305.08	648.57
Jend. Sudirman Road	1865.92	836.45
	Zone area II	
Karaeng Burane Road	6445.00	2758.95
Jend. Ahmad Yani Road	1558.20	8051.25
	Zone area III	
Andi Arsyad Road	1167.00	7060.75
Lahalede Road	8540.00	3919.60
	Zone area IV	
Lingkar Kota Parepare Road	9620.00	3797.65
Jend Muh. Yusuf Road	3108.00	1154.40
Total	61121.5	1154.40

Table 5. Types of side obstacle (HS) events based on the severity and frequency of events

Area Zones and Road		Side Obstacle Event Type (HS) (Weight/Wt, Frequency/Fq)								Total
		Pedestrian (PED)		Parking, Vehicle Stops (PSV)		Vehicles In and Out (EEV)		Slow Vehicle (SMV)		
		Wt	Fq	Wt	Fg	Wt	Fg	Wt	Fg	
I	1	0.5	44	1	55	0.7	284	0.4	124	325.4
	2	0.5	174	1	298	0.7	447	0.4	133	751.1
	3	0.5	51	1	258	0.7	225	0.4	107	483.8
	4	0.5	56	1	49	0.7	383	0.4	424	514.7
II	5	0.5	43	1	36	0.7	128	0.4	109	190.7
	6	0.5	21	1	24	0.7	64	0.4	87	114.1
III	7	0.5	121	1	180	0.7	165	0.4	317	482.8
	8	0.5	148	1	135	0.7	283	0.4	372	555.9
IV	9	0.5	43	1	54	0.7	48	0.4	11	113.5
	10	0.5	4	1	9	0.7	5	0.4	0	14.5
				Total of all segments						3546.5

The scenario simulation shows that a 10% increase in FAR (Scenario A) begins to degrade the level of service on segment Z7 from category B to C. With a 20% increase in FAR (Scenario B), Segment 2 experiences a significant decline in performance to LOS D, while the saturation threshold on other segments continues to approach the critical point. Ultimately, the expansion scenario to the maximum zoning limit (FAR 4.0) is predicted to trigger massive functional failure across almost the entire road network, with the majority of segments (Z2, Z4, Z6, Z7, Z8, and Z10) reaching LOS F or total gridlock. These findings confirm that land use intensity up to the maximum limit without infrastructure mitigation will change the corridor's condition from safe to critically unsafe, as validated in Tables 11–15 and Figure 6.

Table 6. Analysis of free stream velocity, speed, and travel time

Main Corridor Road Zone	Free Flow Speed (MP)	Travel Speed (V_{MP})	Travel Time (W_T)
Zone area I subdistrict Bacukiki Barat			
Mattiro Tasi Road	48.0	44.0	0.11
Bau Massepe Road	49.0	40.5	0.03
Agussalaim Road	49.0	44.5	0.02
Jend. Sudirman Road	53.4	48.5	0.10
Zone area II subdistrict Ujung			
Karaeng Burane Road	33.35	32.0	0.03
Jend. Ahmad Yani Road	33.35	29.5	0.24
Zone area III subdistrict Soreang			
Andi Arsyad Road	34.7	32.0	0.17
Lahalede Road	34,7	32.5	0.01
Zone area IV subdistrict Bacukiki			
J1. M. Yusuf	35.5	35	0.16
Jl. Lingkar	35.5	31	0.18

Table 7. Building floor coefficient values and road performance with Level of Service (LOS)

Main Corridor Roadside Area	Building Floor Coefficient Actual	DS (V/C Ratio)	Capacity (C) (smp/h)	Service Level (LOS)
Zone area I subdistrict Bacukiki Barat				
Mattiro Tasi Road	0.5	0.18	2589.98	A (Free current)
Bau Massepe Road	1.3	0.57	1940.40	C (Limited stable current)
Agussalaim Road	0.9	0.25	2217.60	B (Stable Current)
Jend. Sudirman Road	0.4	0.30	2878.85	B (Stable Current)
Zone area II subdistrict Ujung				
Karaeng Burane Road	0.9	0.11	1995.08	B (Stable Current)
Jend. Ahmad Yani Road	0.6	0.31	2148.55	B (Stable Current)
Zone area III subdistrict Soreang				
Andi Arsyad Road	1.0	0.44	1929.31	B (Stable Current)
Lahalede Road	0.8	0.28	1688.15	B (Stable Current)
Zone area IV subdistrict Bacukiki				
Lingkar Kota Parepare Road	0.3	0.06	2126.63	B (Stable Current)
Jend Muh. Yusuf Road	0.2	0.22	2170.48	A (Free current)

The implementation of performance-based zoning policies (priority maps) derived from SLM analysis classifies ten road segments into three risk categories based on capacity reserves and FAR sensitivity. The Critical (Red) category includes zones with the highest β sensitivity (Z2 and Z7), which require a moratorium on high-intensity development or mandatory physical mitigation before new permits are issued. The Conditional Zone (Yellow) includes the majority of corridors that operate within safe thresholds but are at risk of functional failure, thus requiring a phased review protocol and mitigation if approaching the DS $\geq$ 0.70 threshold. Meanwhile, the Safe (Green) category is identified as a strategic zone for high-intensity urban development because it has extensive network capacity reserves and low FAR sensitivity, in line with the principles of mobility-based sustainable urban growth as detailed in Tables 16 and 17 and Figures 6 and 7.

Table 8. Comparison of separate SLM model parameters (Hypothetical)

Parameter	Z1 (Primart Commercial)	Z2 (Office)	Z3 (Transition)	Z4 (Residential)
Coefficient FAR (β FAR)	+0.150	+0.200	+0.165	+0.130
p-value FAR	<0.01	<0.01	<0.05	<0.05
Coefficient ρ (Spatial Lag)	+0.370	+0.390	+0.350	+0.300
AIC	35.0	28.5	31.2	25.8

Table 9. SLM estimation results with fixed effects and zone interactions

Variable	Coefficient	p-Value	IK 95% Lower	IK 95% On	Information
Konstanta (Intersep ZI)	0.150	<0.01	0.080	0.220	Average minimum DS in the reference Zone (Z1).
FAR (β_1)	+0.150	<0.01	0.075	0.225	Impact of FAR in the reference Zone (Z1).
ρ (Spatial Lag)	+0.370	<0.01	0.240	0.500	Network spillover effect (Constant across all Zones).
HS (β_2)	+0.005	<0.01	0.002	0.008	Side barrier impact.
Cribuan (β_1)	-0.105	<0.01	-0.155	-0.055	Impact of road capacity.
D2 (Office) (γ_2)	+0.120	<0.01	0.040	0.200	Zone 2 fixed effect (Intercept higher than Z1).
D3 (Transition) (%)	+0.030	0.350	-0.050	0.110	Not significant.
D4 (Residential) (74)	-0.080	<0.05	-0.150	-0.010	Zone 4 fixed effect (Intercept lower than Z1).
FAR $\times$ D2 (Interaction) (δ_2)	+0.050	<0.05	0.010	0.090	Slope effect (The FAR $\rightarrow$ DS relationship is steeper in Z2).
FAR $\times$ D3 (Interaction) (δ_1)	+0.015	0.400	-0.025	0.055	Not significant.

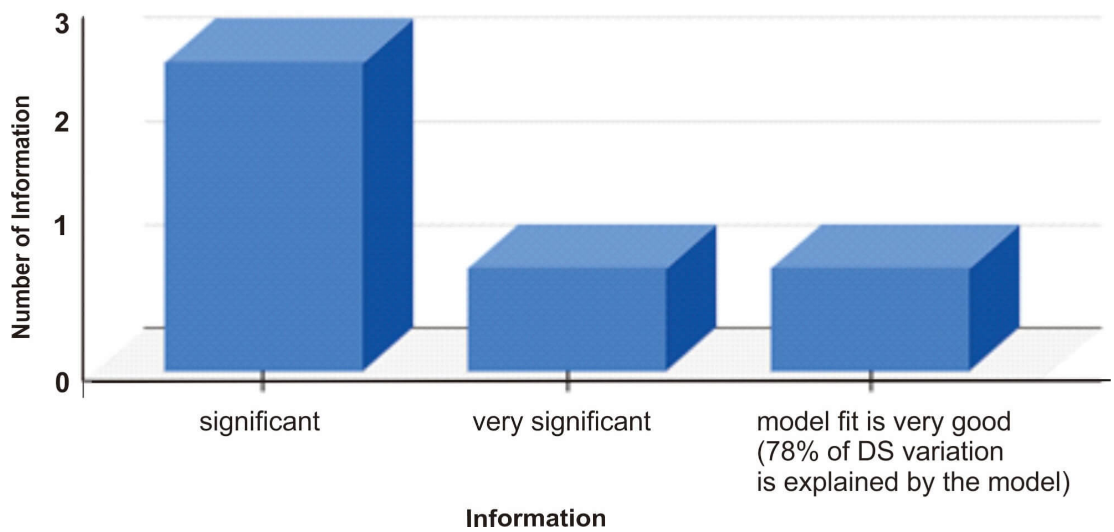


Figure 5. Spatial modeling results graph

Table 10. Model validity analysis

Statistical Test	Hypothetical Value	Significance	Interpretation
Moran's I (Residual OLS)	0.42	Significant ($p < 0.01$)	There is strong positive spatial autocorrelation in the residuals. This indicates that using an OLS model will produce biased coefficients and that poor road performance tends to cluster in nearby areas. A spatial regression model is required.
Lagrange Multiplier (LM)-Lag	Tall	Significant	The Spatial Lag Model (SLM) is more appropriate to use than the Spatial Error Model (SEM).

Table 11. Spatial Lag Model (SLM) modeling results

Variable	Coefficient β	Standard Error (SE)	t-Count	p-Value	IK 95% Lower	IK 95% On	Standardized Coefficient (β)
FAR (Intensity)	+0.184	0.052	3.54	<0.01	0.082	0.286	+0.35
HS (Side obstacles)	+0.006	0.002	3.00	<0.01	0.002	0.010	+0.21
C (Capacity)	-0.100	0.024	-4.17	<0.01	-0.148	-0.052	-0.45
ρ (Spatial Lag)	+0.387	0.066	5.86	<0.01	0.257	0.517	N/A (Endogen)
Constanta	0.201	0.040	5.03	<0.01	0.121	0.281	N/A

Table 12. Results of scenario A with FAR increase +10%

Main Corridor Roadside Area	Building Floor Coefficient Actual	Δ FAR (+10%)	Δ DS ($\times$ 0.184)	DS Baru (Predictable)	Prediction LOS New
Zone area I subdistrict Bacukiki Barat					
Segment 1	0.5	+0.05	+0.009	0.189	A
Segment 2	1.3	+0.13	+0.024	0.594	C
Segment 3	0.9	+0.09	+0.017	0.267	B
Segment 4	0.4	+0.04	+0.007	0.307	B
Zone area II subdistrict Ujung					
Segment 5	0.9	+0.09	+0.017	0.127	A
Segment 6	0.6	+0.06	+0.011	0.321	B
Zone area III subdistrict Soreang					
Segment 7	1.0	+0.10	+0.018	0.458	B–C
Segment 8	0.8	+0.08	+0.015	0.295	B
Zone area IV subdistrict Bacukiki					
Segment 9	0.2	+0.02	+0.004	0.064	A
Segment 10	0.3	+0.03	+0.006	0.226	B

Table 13. Results of scenario B with FAR increase +20%

Main Corridor Roadside Area	Building Floor Coefficient Actual	Δ FAR (+20%)	Δ DS (× 0.184)	DS Baru (Predictable)	Prediction LOS New
Zone area I Subdistrict Bacukiki Barat					
Segment 1	0.5	+0.10	+0.018	0.198	A
Segment 2	1.3	+0.26	+0.048	0.618	C–D
Segment 3	0.9	+0.18	+0.033	0.283	B
Segment 4	0.4	+0.08	+0.015	0.315	B
Zone area II subdistrict Ujung					
Segment 5	0.9	+0.18	+0.033	0.143	A
Segment 6	0.6	+0.12	+0.022	0.332	B
Zone area III subdistrict Soreang					
Segment 7	1.0	+0.20	+0.037	0.477	B–C
Segment 8	0.8	+0.16	+0.029	0.306	B
Zone area IV subdistrict Bacukiki					
Segment 9	0.2	+0.04	+0.007	0.067	A
Segment 10	0.3	+0.06	+0.011	0.231	B

Table 14. Output scenario C FAR 4.0 per segment

Main Corridor Roadside Area	Building Floor Coefficient Actual	Δ FAR (Maks, 4.0)	Δ FAR	Δ DS (× 0.184)	DS Baru (Predictable)	Prediction LOS New
Zone area I Subdistrict Bacukiki Barat						
Segment 1	0.5	4.0	+3.5	+0.644	0.824	A–E
Segment 2	1.3	4.0	+2.7	+0.497	1.067	C–F
Segment 3	0.9	4.0	+3.1	+0.570	0.820	B–F
Segment 4	0.4	4.0	+3.6	+0.662	0.962	B–F
Zone area II subdistrict Ujung						
Segment 5	0.9	4.0	+3.1	+0.570	0.680	A–D
Segment 6	0.6	4.0	+3.4	+0.626	0.936	B–F
Zone area III subdistrict Soreang						
Segment 7	1.0	4.0	+3.0	+0.552	0.992	B–F
Segment 8	0.8	4.0	+3.2	+0.589	0.869	B–F
Zone area IV subdistrict Bacukiki						
Segment 9	0.2	4.0	+3.8	+0.699	0.759	A–E
Segment 10	0.3	4.0	+3.7	+0.681	0.901	B–F

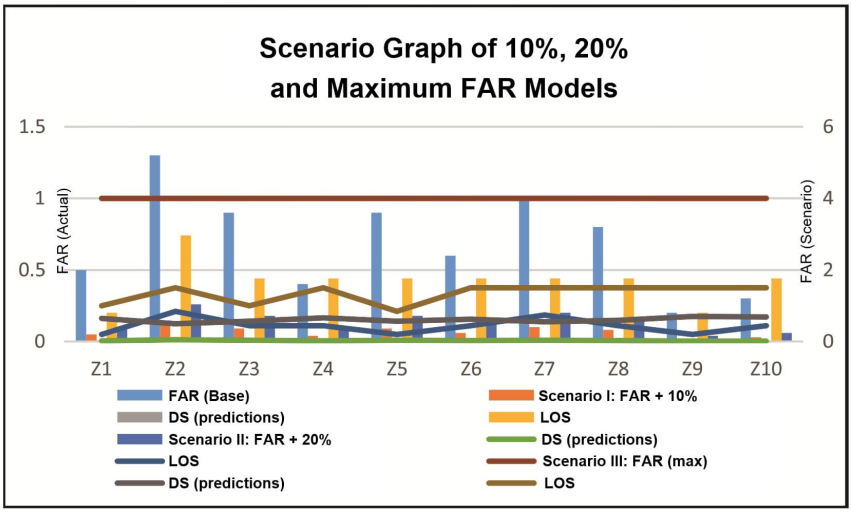


Figure 6. Graphic scenario model

Table 15. Performance matrix results with DS in modeling

Performance Matrix	Baseline	Scenario FAR 4.0 (Prediction)	Critical Change
Average DS corridor	0.286	0.864	Go on 202%
Segment percentage LOS D/E/F (DS $\geq$ 0.75)	0%	80%	Network failed
Segment percentage LOS F (DS > 1.0)	0%	20%	Two segments collapse

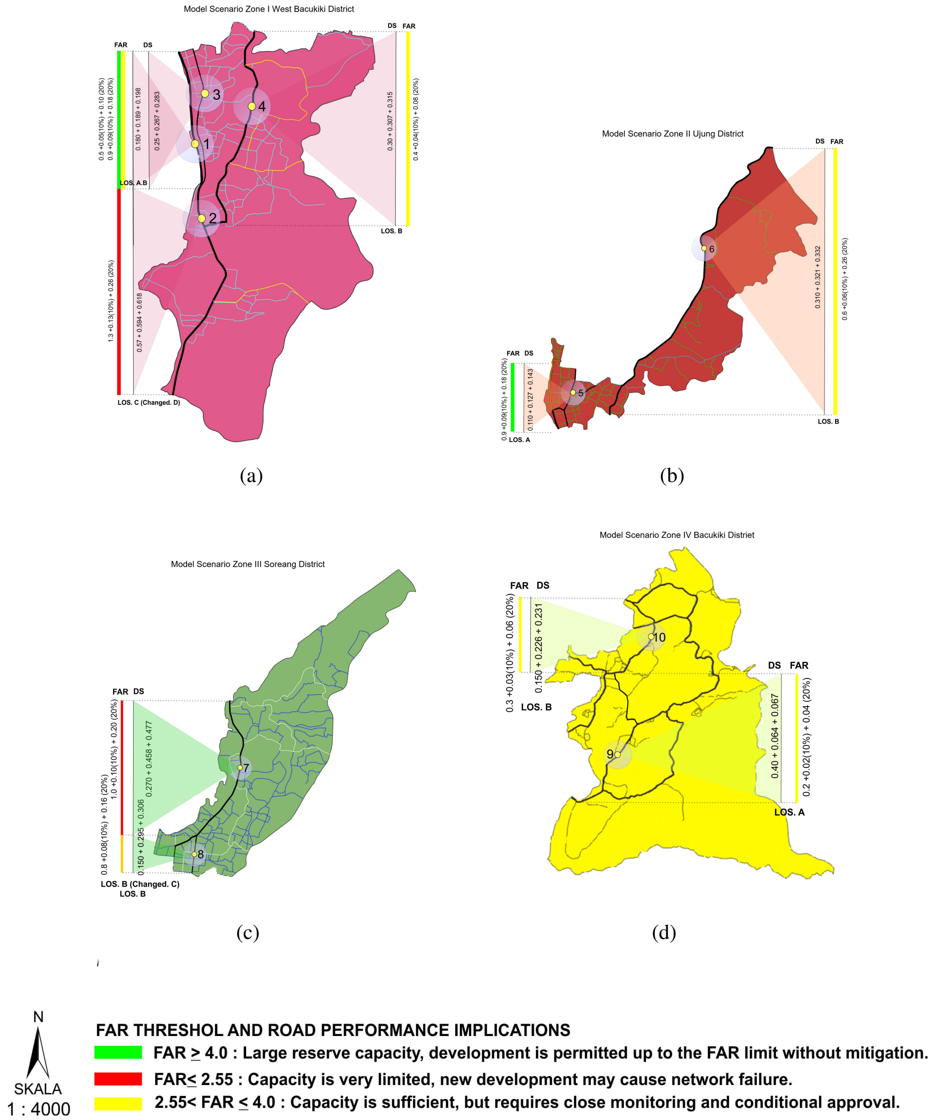


Figure 7. Distribution of building floor coefficient values with road performance DS ratio

Table 16. Priority classification based on FAR

Priority Category	Threshold FAR	Road Performance Implications	Warna Peta
Red (Critical)	FAR* $\leq$ 2.55	Capacity is very limited. New development may cause network failure.	Red
Yellow (Controlled)	2.55 < FAR* < 4.0	Capacity is sufficient, but requires close monitoring and conditional approval.	Yellow
Green (Widely Luas)	FAR* $\geq$ 4.0	Large reserve capacity. Development is permitted up to the FAR* limit without mitigation.	Green

Table 17. Detail segmen berdasarkan klasifikasi prioritas

Segment	Zone Classification	DS current	FAR current	FAR Recom	Priority Category
Z2	Office(Z2)	0.57	1.3	2.20	Red
Z7	Office (Z2)	0.44	1.0	2.55	Red
Z4	Transition (Z3)	0.30	0.4	3.13	Yellow
Z6	Residential (Z4)	0.31	0.6	3.53	Yellow
Z10	Transition (Z3)	0.22	0.3	3.51	Yellow
Z8	Commersial (Z1)	0.28	0.8	3.93	Yellow
Z3	Transition (Z3)	0.25	0.9	3.93	Yellow
Z1	Commersial (Z1)	0.18	0.5	4.30	Green
Z9	Residential (Z4)	0.06	0.2	4.80	Green
Z5	Residential (Z4)	0.11	0.9	5.17	Green

4 Conclusions

This study empirically validates that the functional relationship between vertical space utilization intensity FAR and road network performance in the Parepare corridor is controlled by spatial dynamics, where the use of the SLM is able to explain 78% of the variability in the DS (R^2 = 0.78). The main finding is a positive autocorrelation coefficient (ρ = +0.387), which proves that congestion is a network phenomenon with a significant spillover effect, where an increase in FAR per unit contributes +0.345 to an increase in DS. The scenario simulation results show that the current development strategy is unsustainable; expanding the FAR to the maximum zoning limit (4.0) is predicted to trigger total functional failure (LOS E and F) in the majority of segments, especially in the Office Zone (Z2) as the most sensitive point (β_{FAR} = +0.200). Therefore, this study recommends a transition from a uniform FAR policy to performance-based zoning with differential controls, including setting a FAR threshold of $\leq$ 2.20 in critical segments and integrating mandatory mitigation through capacity improvements and reduction of side barriers to prevent systemic collapse of the road network.

Author Contributions

Conceptualization, M.B., M.N.A., M.M., and A.S.; methodology, M.B., M.N.A., and M.M.; software, M.B.; Validation, M.B., M.M., and M.N.A.; formal analysis, M.B. and M.M.; investigation, M.B., M.M., and A.S.; resources, M.B.; data curation, M.B., M.M., and A.S.; writing—original draft, M.B.and M.M.; writing—review and editing, M.B., M.M., M.N.A., and A.S.; visualization, M.B.; supervision, M.B. and M.M.; project administration, M.B., M.M., and M.N.A.; funding acquisition, M.B. and M.M. All authors have read and approved the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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