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Evaluating Connectivity and Effectiveness of the Road Transportation Network in West Bangka Regency

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ABSTRACT

Transportation infrastructure is essential for regional integration and economic development in West Bangka Regency. However, corridor-oriented growth has led to uneven connectivity and a strong reliance on limited road corridors. This study evaluates the connectivity and effectiveness of the regional transportation network using spatial, topological, and operational indicators based on a graph representation comprising 12 links and 10 nodes that reflect the main inter-district road structure. The analysis integrates Alpha (α), Beta (β), and Gamma (γ) indices, road density, Accessibility Index (AI), Volume-to-Capacity (V/C) ratio, Level of Service (LOS), Travel Time Efficiency (TTE), and a composite Network Effectiveness Index (NEI). Results show low structural connectivity (Beta 0.20–0.33; Gamma 0.08–0.13; negative Alpha; density 0.039), indicating a tree-like configuration with minimal redundancy. Although operational performance remains stable (V/C 0.02–0.59; LOS A–C), accessibility is moderate to low (AI 0.189; travel time 90–111 minutes). The overall NEI indicates moderate effectiveness but limited network resilience. These findings highlight the need for policymakers to prioritize the development of alternative and transversal road links to reduce dependence on single corridors, improve accessibility, and strengthen long-term transportation resilience. The proposed approach provides a quantitative framework for infrastructure planning in corridor-dominated developing regions.

INTRODUCTION

Transportation infrastructure plays a strategic role in supporting regional development, economic growth, and spatial integration. An efficient and well-connected transportation network facilitates the mobility of people and goods, reduces logistics costs, and improves accessibility between economic centers and service areas. Conversely, inadequate transportation connectivity may lead to regional disparities, limited accessibility, longer travel times, and higher transportation costs, ultimately hindering regional competitiveness and socio-economic development (Rodrigue, 2024; Scott et al., 2006).

From a transportation planning perspective, network connectivity is a fundamental indicator of the level of linkage between nodes and links within a transportation system. High connectivity allows multiple route alternatives, distributes traffic flows more evenly, and enhances network resilience against congestion and infrastructure disruptions (Ganin et al., 2017; Suprayitno, 2018). Furthermore, connectivity quality reflects the ability of transportation infrastructure to serve regional movement efficiently and support logistics distribution both locally and regionally (Ridhoni et al., 2025).

Along with regional growth and population mobility, the demand for effective and sustainable transportation systems continues to increase. Urban expansion, industrial development, and tourism activities contribute to rising transportation demand, often exceeding existing infrastructure capacity. Therefore, evaluating the performance of transportation networks, particularly in terms of connectivity and accessibility, becomes essential in supporting balanced regional development (Banister, 2008; Ortúzar & Willumsen, 2011).

Transportation connectivity is also widely recognized as a critical factor in strengthening regional economic integration and improving competitiveness. Previous studies have demonstrated that well-connected transportation networks contribute significantly to trade efficiency, industrial productivity, and regional economic interactions (Abbas & Wei, 2022; Komornicki & Goliszek, 2023; Rosik & Wójcik, 2023). Moreover, transportation networks play a vital role in facilitating access to public services, employment opportunities, and social mobility, thereby promoting inclusive regional development (Allen & Farber, 2020; Auttha et al., 2025). owever, many regions in developing countries, including Indonesia, still face challenges in establishing an integrated transportation network. Geographic conditions, uneven distribution of infrastructure, and limited transportation capacity often result in suboptimal transportation performance and regional accessibility disparities (Gado et al., 2024; Sitorus et al., 2016). These conditions frequently lead to inefficient logistics systems, increased operational costs, and reduced regional connectivity.

West Bangka Regency, located in the Bangka Belitung Islands Province, possesses significant economic potential supported by mining, plantation, marine resources, and tourism sectors. The development of these sectors depends heavily on a reliable transportation network connecting production areas, distribution centers, and regional service hubs. However, as an archipelagic region with dispersed settlements and diverse geographic characteristics, West Bangka faces substantial challenges in maintaining effective transportation connectivity and accessibility.

Several previous studies have evaluated transportation network connectivity using quantitative indices, such as beta, gamma, and network density, to assess the level of linkage between network nodes and links. The beta index measures the relationship between the number of road links and nodes, while the gamma index represents the degree of network connectivity relative to the maximum possible connections (Mafflichah et al., 2023; Ridhoni et al., 2025). In addition, transportation network effectiveness is commonly assessed through accessibility indicators and road performance evaluation, such as Level of Service (LOS), which measures the network's ability to accommodate transportation demand (Akinsulire, 2020; Indra Permana et al., 2025; K.C. & S.T., 2009; Pelawi et al., 2023; Tamalah et al., 2024).

Despite extensive research on transportation network connectivity, several research gaps remain. First, most previous studies focus primarily on physical connectivity analysis without integrating service performance indicators such as accessibility, travel time reliability, and transportation efficiency. As a result, existing studies often provide partial evaluations of transportation network performance (Lee et al., 2022; Zang et al., 2022). Second, studies examining transportation network connectivity at the regency or regional scale, particularly in archipelagic areas such as West Bangka Regency, remain limited. Most transportation connectivity studies are concentrated in urban or metropolitan areas, leaving rural and island-based regions underrepresented in the literature (Abbas & Wei, 2022; Rodrigue, 2024). Third, there is still considerable variation in methodologies and performance indicators used to evaluate transportation network effectiveness. Differences in analytical approaches often lead to inconsistent evaluation results, making it difficult to compare network performance across regions and develop standardized transportation planning strategies (Lin et al., 2021; Scott et al., 2006; Taylor, 2017).

Therefore, despite the strategic role of the road system, previous studies and planning documents have not simultaneously evaluated the structural connectivity and functional effectiveness of the road transportation network using integrated spatial and topological performance indicators, particularly at the regional scale of West Bangka Regency. This lack of comprehensive assessment limits the ability to identify critical network deficiencies and prioritise infrastructure improvements based on quantitative evidence. To address this gap, this study evaluates both the connectivity and effectiveness of the existing road network using quantitative network indices and performance measures. The study provides an objective identification of infrastructure gaps and offers evidence-based recommendations to improve network performance. The findings are expected to contribute to more effective and sustainable regional transportation planning and support balanced regional development.

RESEARCH METHODS

Research Approach

This study adopts a quantitative-descriptive and analytical approach to evaluate the connectivity and effectiveness of the transportation network in West Bangka Regency. The analysis combines graph theory–based network connectivity indices with transportation performance indicators to provide a comprehensive assessment of the regional transportation system (Kim et al., 2023; Li et al., 2025; Munawar et al., 2023). The methodology is designed to capture both the structural characteristics of the road network and its functional performance in serving regional mobility demands (Banister, 2008).

The study area encompasses the entire administrative boundary of West Bangka Regency, Bangka Belitung Islands Province, Indonesia, as shown in Figure 1. Dispersed settlements, economic activity centres, and diverse geographic conditions typical of archipelagic areas characterise the region. The analysed transportation network primarily consists of arterial, collector, and local roads connecting sub-districts, economic centres, ports, and service facilities.

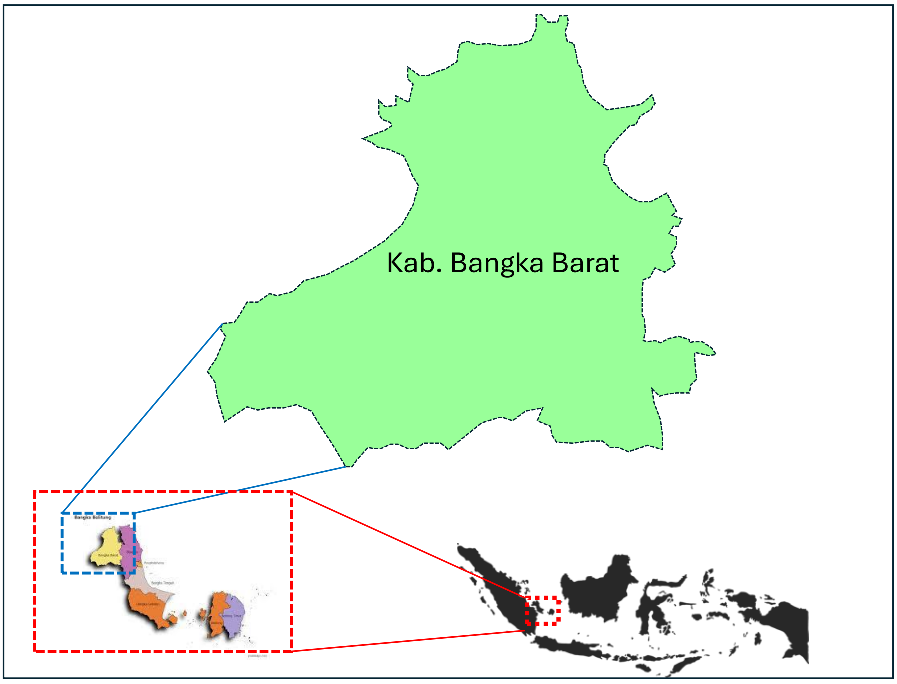

Figure 1. Research Location in West Bangka Regency, Bangka Belitung Islands Province

Data Collection

The study employs a combination of primary and secondary data to analyse regional transportation network connectivity and effectiveness. Secondary data consist of road network maps and spatial information, including road hierarchy, segment length, and network connectivity, obtained from local government agencies and geospatial databases. Traffic volume data, such as Annual Average Daily Traffic (AADT) and peak-hour traffic, are also obtained from transportation authorities to represent traffic demand. In addition, regional planning documents, including the Regional Spatial Plan (RTRW), transportation master plans, and regional development reports, provide policy context and future development directions. Socioeconomic data, particularly population distribution and the location of activity centres, are incorporated to reflect travel demand patterns and spatial interactions within the study area.

Primary data are obtained through direct field surveys and measurements conducted on 12 road segments and 10 nodes distributed across six districts in West Bangka Regency. These include on-site measurements of road segment length and width to ensure the accuracy of the network's geometric characteristics. Traffic volume surveys are carried out through direct vehicle counts on selected road segments to capture actual traffic flow conditions and demand characteristics. Furthermore, field observations are conducted to verify inter-road connectivity, functional road classification, and existing road conditions, and to identify potential capacity constraints and bottlenecks. Travel time surveys are also conducted to evaluate network performance and accessibility between nodes and activity centres. All spatial and field data are subsequently processed using Geographic information System (GIS) software to develop a digital transportation network model, which serves as the basis for analysing the connectivity and effectiveness of the regional transportation network.

Transportation Network Modeling

The road network is conceptualized as a graph to capture the structural characteristics of the transportation system systematically. In this representation, nodes correspond to key spatial points such as road intersections, transportation terminals, ports, and major activity centers that generate and attract travel demand (Li et al., 2025; Munawar et al., 2023). At the same time, links represent road segments that physically connect these nodes and facilitate traffic flow. Modeling the road system as a graph provides a robust analytical framework for examining the network's spatial configuration and functional performance. This approach enables the application of various connectivity indices, such as network density and redundancy measures, as well as accessibility analyses that assess the ease of movement between locations. By relying on established transportation network theory, the graph-based representation enables quantitative evaluation of network efficiency, integration, and resilience, thereby supporting a comprehensive understanding of how well the road network serves regional mobility and connectivity needs.

Connectivity Analysis

Transportation network connectivity is quantitatively assessed using graph-theoretic indicators that describe network structure, link availability, and redundancy. The analysis uses the Beta Index (β), Gamma Index (γ), Alpha Index (α), and road network density, which are commonly adopted in transportation and regional network studies to evaluate the degree of network integration and performance.

The Beta Index (β) represents the ratio between the number of links (L) and the number of nodes (N), and is expressed as (Munawar et al., 2023):

$$\beta = \frac{L}{N} \tag{1}$$

This index provides a measure of network complexity by indicating the average number of connections per node. Higher β values imply increased connectivity and improved route availability, whereas lower values indicate a sparsely connected network with limited structural integration.

The Gamma Index (γ) evaluates the level of connectivity relative to the maximum number of links possible in a planar network. It is defined as (Munawar et al., 2023):

$$\gamma = \frac{L}{3(N-2)} \tag{2}$$

The γ index ranges from 0 to 1, with values approaching 1 indicating a highly connected network structure. Lower γ values suggest underutilization of potential linkages and reflect limited network completeness.

The Alpha Index (α) measures network redundancy by quantifying the proportion of independent cycles relative to the maximum number of cycles that can exist within the network. It is calculated as (Munawar et al., 2023):

$$\alpha = \frac{L-N+1}{2N-5} \tag{3}$$

This index captures the availability of alternative routes and reflects the resilience of the transportation network. Higher α values indicate greater redundancy and robustness against link disruptions, while values close to zero characterize tree-like networks with minimal alternative paths.

In addition to topological indices, road network density (D) is used to evaluate the spatial intensity of transportation infrastructure. Road network density is calculated as (Li et al., 2025; Munawar et al., 2023):

$$D = \frac{\sum X}{A} \tag{4}$$

where X denotes the total length of road segments, and A represents the area of the study region. This indicator reflects the extent of network coverage and supports comparative analysis across regions with different spatial scales.

The combined application of these connectivity measures enables a systematic classification of transportation network integration and facilitates the identification of spatial units with low connectivity or insufficient redundancy. The results provide an analytical basis for diagnosing structural deficiencies and informing transportation planning strategies aimed at improving accessibility, network efficiency, and system resilience.

Effectiveness and Performance Analysis

The effectiveness of the transportation network is evaluated using a set of functional performance indicators that capture accessibility, operational performance, and overall network efficiency. Accessibility is measured based on travel time and distance from each analysis zone to major activity centers, such as district capitals, economic hubs, ports, and service facilities. In this study, accessibility is expressed using an inverse travel-time formulation, where lower travel time indicates higher accessibility:

$$AI_i = \sum_{j=1}^{m} \frac{W_j}{T_{ij}} \tag{5}$$

where AI is the accessibility index of zone i, T_{ij} is the travel time between zone i and activity center j, W_j is the weight representing the importance of activity center j, and m is the total number of activity centers considered.

Road performance is assessed using the Level of Service (LOS) concept, which is quantified through the Volume-to-Capacity (V/C) ratio (Li et al., 2025; Munawar et al., 2023):

$$\left(\frac{V}{C}\right)_k = \frac{V_k}{C_k} \tag{6}$$

where V_k is the traffic volume on road segment k and C_k is its corresponding capacity. Based on the V/C ratio, LOS A–C indicate stable flow conditions with acceptable operating speeds, while LOS D–F represent unstable to congested conditions with reduced service quality.

To further evaluate operational efficiency, travel time efficiency is analyzed by comparing observed travel time with ideal or free-flow travel time, expressed as:

$$TTE_k = \frac{T_{ff,k}}{T_{obs,k}} \quad (7)$$

where $T_{ff,k}$ is the free-flow travel time and $T_{obs,k}$ is the observed travel time on road segment k. Lower values of this ratio indicate higher levels of delay and inefficiency.

Finally, an integrated Network Effectiveness Index (*NEI*) is developed to provide a comprehensive assessment of overall network performance. Each indicator is first normalized to a comparable scale, and the composite index is calculated as:

$$NEI = \alpha CI + \beta AI + \gamma PI \quad (8)$$

where CI is the connectivity index, $AI$is the accessibility index, and $PI$is the performance indicator derived from the Volume-to-Capacity (V/C) ratio and travel time efficiency. The weighting coefficients α, β, and γ, with the condition $\alpha + \beta + \gamma = 1$, are determined based on field-based empirical considerations. Specifically, the weighting of the connectivity index (α) reflects the existing transportation network connectivity conditions obtained from field observations and network mapping. The accessibility weight (β) is derived from the best travel distance and route efficiency based on field surveys conducted on 12 selected road segments, representing actual accessibility conditions. Meanwhile, the performance weight (γ) is based on the operational performance of the network, represented by the Volume-to-Capacity (V/C) ratio obtained from traffic volume and road capacity measurements collected during field surveys. This empirically based weighting approach ensures that the NEI reflects the actual structural, spatial, and operational characteristics of the transportation network. The composite index enables a holistic evaluation of transportation network effectiveness and supports comparative analysis across different regions or planning scenarios.

RESULTS AND DISCUSSION

Transportation Network Characteristics

The transportation network of West Bangka Regency consists of arterial, collector, and local roads connecting sub-district centers, economic activity areas, ports, and service facilities. Spatial analysis shows that the road network exhibits an uneven distribution, with higher road density concentrated in central and coastal areas. In contrast, peripheral and rural areas remain relatively less connected (see Figure 2).

The graph-based network model indicates that the transportation system is dominated by linear and branching structures, particularly in rural zones, which limits route alternatives and increases dependency on specific road segments. This network configuration reflects typical characteristics of regional and archipelagic transportation systems, where geographic constraints and dispersed settlements influence infrastructure development. These characteristics suggest that the overall network structure may constrain mobility efficiency, particularly during peak traffic periods or when disruptions occur on critical links.

Based on Table 1, transportation facilities in West Bangka Regency in 2025 are predominantly land-based. In total, there are 62 land vehicle facilities distributed across six districts, with the highest number located in Simpang Teritip District (13 units), followed by Kelapa and Jebus (11 units each), and Tempilang, Mentok, and Parittiga (9 units each). The data indicate that land vehicle facilities are the most dominant mode, totaling 62 points across all districts. In contrast, maritime transportation facilities are concentrated in the Mentok District, which includes a passenger port serving as the main gateway for entry and exit to the regency.

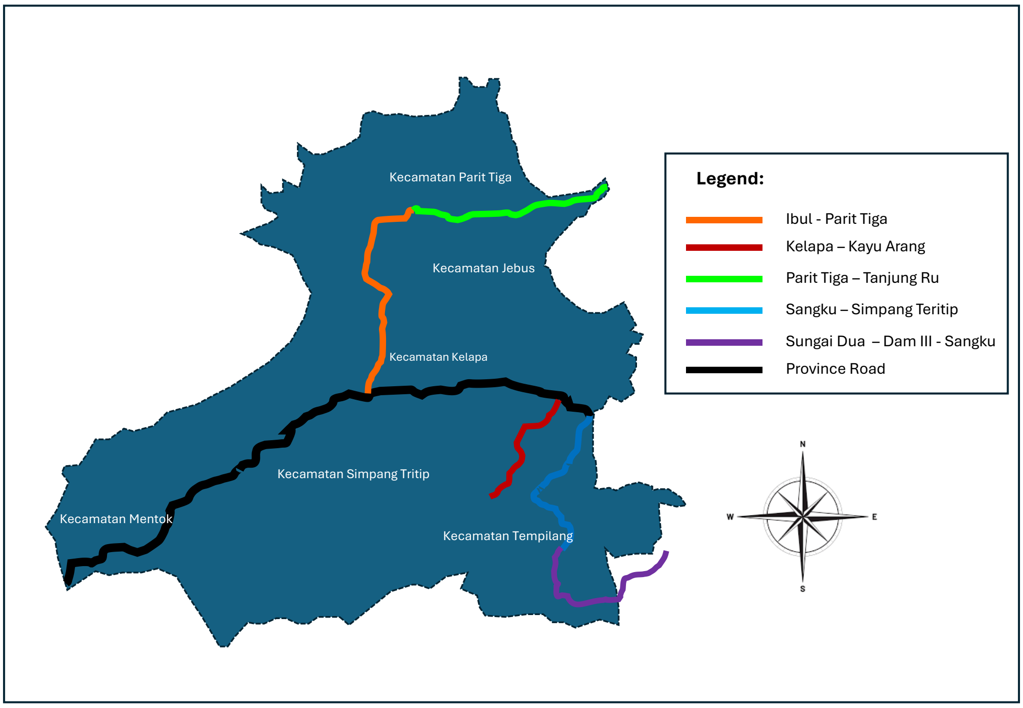

Figure 2. Map of the Existing Road Network of West Bangka Regency

Mentok District functions as the primary regional transportation node, characterized by a Type B terminal serving interregional and city movements and a seaport connecting West Bangka with other areas within the Bangka Belitung Islands Province. This transportation node is directly connected to the national road network, which serves as the main movement corridor linking Mentok to other districts, thereby strengthening its role as the central hub for passenger and goods distribution. Meanwhile, integrated land–water transportation facilities (multimodal) are recorded only in Parittiga District (1 unit). At the regency level, there is only one official terminal and one seaport, and no air transportation facilities are available.

In Parittiga and Kelapa Districts, existing terminal locations currently function as informal terminals or passenger pick-up and drop-off points; however, they have not yet been officially designated as formal terminals. According to the Regional Spatial Plan (RTRW), both locations are planned to be developed into Type C terminals to serve intra-regional transportation and enhance local-scale accessibility. This condition reflects the need to upgrade transportation node facilities in areas experiencing increasing mobility activities. In addition to transportation nodes, supporting facilities such as fuel stations (SPBU) and electric vehicle charging stations (SPKLU) are distributed along the main road corridors connecting activity centers, thereby supporting land-based mobility for both local and inter-district travel.

Table 1 presents the distribution of transportation facilities in West Bangka Regency, showing that land transportation dominates across all subdistricts, with a total of 62 land vehicle units. The highest number is found in Simpang Teritip (13 units), followed by Kelapa and Jebus (11 units each), while Tempilang, Mentok, and Parittiga each have 9 units. Water transportation facilities are not available in any subdistrict. However, integrated land and water transportation is available in Parittiga, with 1 unit, making it the only multimodal facility in the regency. Airport facilities are not available in any subdistrict. Supporting infrastructure includes 1 terminal and 1 harbor, both located in Mentok, underscoring its role as the region's primary transportation hub. Overall, these data indicate that transportation infrastructure in West Bangka Regency is heavily reliant on land transport, with limited multimodal integration and centralized supporting facilities.

Tabel 1. Transportation Facilities in West Bangka Regency

Subdistrict	Land vehicle (unit)	Water Transportation (unit)	Land vehicle and Water Transportation (unit)	Airport (unit)	Terminal	Harbor
Kelapa	11	0	0	0	0	0
Tempilang	9	0	0	0	0	0
Mentok	9	0	0	0	1	1
Simpang Teritip	13	0	0	0	0	0
Jebus	11	0	0	0	0	0
Parittiga	9	0	1	0	0	0
Kab. Bangka Barat	62	0	1	0	1	1

Connectivity Analysis Results

The connectivity structure of the existing road network in West Bangka Regency, as interpreted from the spatial map, reflects a predominantly corridor-based configuration with a strong east–west orientation. The main arterial and collector roads form the backbone connecting major activity centers such as Mentok, Simpang Teritip, Jebus, Parittiga, Tempilang, and Kelapa. However, much of the secondary and rural road system exhibits a tree-like branching pattern with limited closed circuits. This structural pattern indicates that while basic inter-district accessibility is available, the overall network redundancy remains relatively low.

Based on the Service Center Map (Peta Pusat Pelayanan) of West Bangka Regency, the connectivity analysis can be interpreted more specifically in relation to the spatial hierarchy of activity centers. The map illustrates the distribution of regional and local service centers across the regency, including primary urban centers and sub-district growth nodes. Mentok serves as the main regional service center (PKW), while other districts, such as Kelapa, Jebus, Parittiga, Simpang Teritip, and Tempilang, act as secondary service centers (PKL or growth centers). Spatially, these centers are distributed along a dominant west–east and southwest–northeast corridor, indicating a corridor-based regional development pattern.

Figure 3. Existing condition of the road network in West Bangka Regency

Additional interpretation based on Table 2 further clarifies the structural characteristics of individual road sections within the provincial network. The table presents the connectivity analysis of the provincial road network in West Bangka Regency (see Figures 2, 3, and 4) based on a segment-level graph representation, indicating a structurally simple, weakly interconnected system. With 12 segments forming the analytical edges, the computed Beta index ranges from 0.20 to 0.33, indicating a low link-to-node ratio. Such values characterize a sparse network in which the number of connections remains limited relative to the number of structural points. Although the Ibul–Parit Tiga corridor shows comparatively higher β values, the overall network still falls within the low structural connectivity category.

The Gamma index, ranging from 0.08 to 0.13, further confirms that the network achieves only a small proportion of its theoretical maximum connectivity for a planar system. It indicates minimal cross-linkages between corridors and a lack of transversal connections that would otherwise enhance route alternatives. In practical terms, the provincial road system operates predominantly through linear corridors rather than an integrated grid, thereby limiting inter-district connectivity and reducing overall network cohesion.

Moreover, the Alpha index values (−0.47 to −0.37) indicate the absence of network cycles, which theoretically corresponds to an alpha value of zero. It confirms that the provincial road system exhibits a tree-like structure, with no loops or redundant paths. Consequently, the network is structurally vulnerable, as any disruption along a critical segment may directly affect accessibility across connected areas. From a connectivity standpoint, the results highlight the need for additional linking segments to increase redundancy and enhance the structural robustness of the regional transport network.

Table 2. Transportation Facilities in West Bangka Regency

No	Road Section Name	Road Length, *X* (Km)	Road Width (m)	Area region, A (Km^2)	*L*	*N*	β	γ	α
1	Sungai Dua - Dam III - Sangku 1	10.3	10	2820.61	2	10	0.20	0.08	-0.47
2	Sungai Dua - Dam III - Sangku 2	6.44	10		2	10	0.20	0.08	-0.47
3	Sangku - Simpang Tempilang 1	13.6	10		2	10	0.20	0.08	-0.47
4	Sangku - Simpang Tempilang 2	7.1	10		2	10	0.20	0.08	-0.47
5	Kelapa - Kayu Arang 1	6.9	8		2	10	0.20	0.08	-0.47
6	Kelapa - Kayu Arang 2	9.24	8		2	10	0.20	0.08	-0.47
7	Ibul - Parit Tiga 1	14.3	12		4	12	0.33	0.13	-0.37
8	Ibul - Parit Tiga 2	3.3	12		4	12	0.33	0.13	-0.37
9	Ibul - Parit Tiga 3	7.48	12		4	12	0.33	0.13	-0.37
10	Ibul - Parit Tiga 4	5.24	12		4	12	0.33	0.13	-0.37
11	Parit Tiga - Tanjung Ru 1	11.9	12		2	10	0.20	0.08	-0.47
12	Parit Tiga - Tanjung Ru 2	13.8	8		2	10	0.20	0.08	-0.47

In addition to topological indices, road network density (*D*) is used to evaluate the spatial intensity of transportation infrastructure within the study area. The calculated density of 0.039 indicates a relatively low concentration of provincial road infrastructure within the regency's spatial extent. This low density reinforces the findings derived from β, γ, and α indices, suggesting limited spatial coverage and weak infrastructural penetration across the territory. A low-density network, combined with minimal redundancy, implies constrained accessibility in peripheral areas and highlights the importance of strategic network expansion to improve overall spatial connectivity.

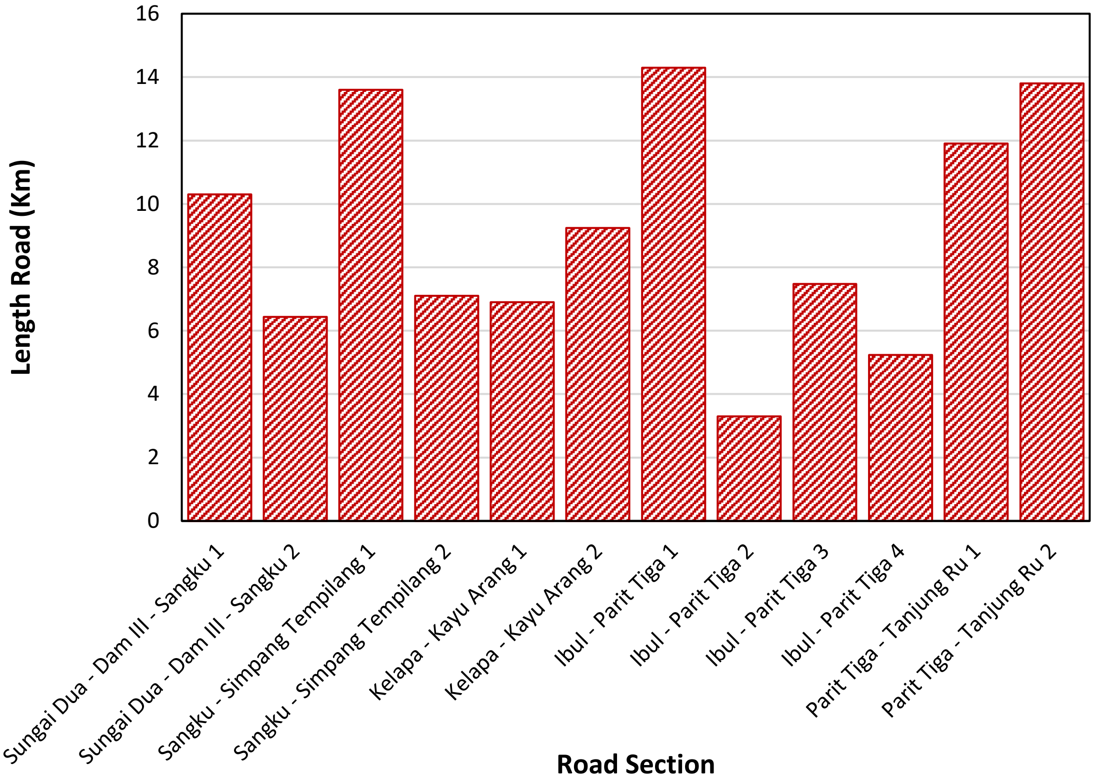

Figure 4. Road length of the Existing Road Network of West Bangka Regency

Effectiveness and Performance Analysis

The effectiveness of the transportation network was evaluated using accessibility indices, travel time efficiency, volume-to-capacity (*V/C*) ratios, and Level of Service (LOS) indicators. Based on the results of the road network performance analysis using the Volume-to-Capacity (*V/C*) Ratio indicator, the values range from 0.02 to 0.59 (see Figure 5), indicating that, in general, the transportation network's operational condition in the study area remains within a stable category. The highest *V/C* value was recorded in Mentok District at 0.59, derived from a traffic volume of 667 pcu/hour and a road capacity of 1,112 pcu/hour. This value falls under Level of Service (LOS) *C*, indicating stable traffic flow with increasing vehicle interactions but not reaching saturated conditions. This finding reinforces the Mentok District's role as the primary regional transportation node, with higher movement intensity than in other districts. In contrast, the lowest *V/C* value of 0.02 was observed in Kelapa and Parittiga Districts, both classified as LOS A. This condition reflects free-flow traffic with very low capacity utilization, indicating that the available infrastructure still has substantial reserve capacity and has not yet been optimally utilized.

From an accessibility perspective, the Accessibility Index (*AI*) calculated using the inverse travel-time approach was 0.189. This value was obtained from the cumulative contribution of four activity centers: district-level government centers, economic zones, the port, and tourism areas, taking into account their respective importance weights and travel times to these locations. The largest contribution to the AI value originates from tourism areas, which have the highest weight and relatively shorter travel times compared to other activity centers. Overall, an *AI* value of 0.189 indicates a moderate to relatively low level of accessibility, given that travel times to most activity centers remain within 90–111 minutes. It suggests that although the road network has not yet experienced significant capacity pressure, spatial efficiency in accessing major activity centers still needs improvement.

Integratively, the combination of the *V/C* Ratio and Accessibility Index results reveals a structural imbalance within the regional transportation system (see Figure 5). Mentok District bears the highest traffic load as the main activity hub, while several other districts still possess underutilized infrastructure capacity. Meanwhile, the suboptimal level of accessibility highlights the need to enhance connectivity and reduce travel times between activity centers. Therefore, future transportation network development strategies should focus on strengthening inter-district connectivity, promoting a more balanced distribution of growth centers, and optimizing road capacity utilization to improve the overall effectiveness and performance of the transportation network.

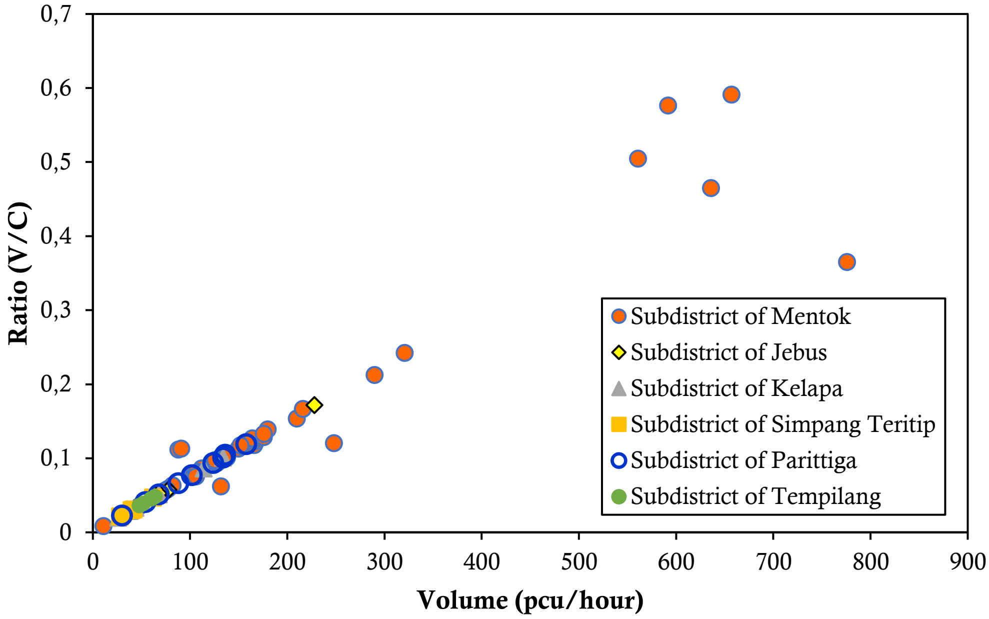

Figure 5. *V/C* ratio for each sub-district in West Bangka Regency

To obtain a comprehensive overview of the transportation network's effectiveness, all indicators were integrated into a single Network Effectiveness Index (*NEI*). This composite index combines the Connectivity Index (*CI*), Accessibility Index (*AI*), and Performance Indicator (*PI*), with the *PI* derived from the *V/C* Ratio and Travel Time Efficiency (*TTE*). Prior to aggregation, each indicator was normalized onto a comparable scale to ensure proportional contribution. By applying weighting factors α, β, and γ, whose sum equals one, the *NEI* reflects a balanced representation of the network's structural characteristics (connectivity), the ease of reaching activity centers (accessibility), and its operational traffic performance.

Referring to the previous results, the *AI* value of 0.189 indicates that accessibility still needs improvement. At the same time, the variation in the *V/C* Ratio (0.02–0.576) suggests that, in general, the network operates under stable conditions. When combined with relatively favorable *TTE* values across most road segments, the *PI* tends to fall within a moderate category. Accordingly, the *NEI* for this region is estimated to be in the moderate effectiveness category, indicating that, structurally and operationally, the transportation network has not yet experienced critical capacity pressures. However, further improvements in connectivity and travel efficiency are still necessary to support more equitable regional development. This composite index approach enables a more holistic evaluation and facilitates comparative analysis between sub-districts as well as scenario-based planning simulations in the future.

Comparative Studies

A comparative evaluation with previous studies highlights consistent patterns regarding corridor-dependent transportation systems. The current study shows that the Beta index ranges from 0.20 to 0.33, the Gamma index from 0.08 to 0.13, and the Alpha index from −0.47 to −0.37, indicating a structurally sparse, tree-like network with minimal redundancy and limited alternative routes. These values are generally lower than those reported by Munawar Hermawati et al. (2018), where transportation networks with stronger inter-node linkages exhibited higher connectivity indices, reflecting more developed and integrated network structures.

Similarly, the Volume-to-Capacity (V/C) ratio in the present study ranges from 0.02 to 0.576, indicating that most road segments operate under stable conditions with substantial unused capacity. In contrast, previous studies commonly reported higher V/C ratios in more interconnected urban networks, reflecting greater traffic intensity and functional utilization of network redundancy. The relatively low V/C values observed in West Bangka Regency suggest that the network's limitation lies not in capacity saturation but in structural connectivity and spatial coverage.

These findings are consistent with the conclusions of (Munawar et al., 2023),(Pratama et al., 2024), Sampetoding et al., (2025) who emphasized that travel time and travel distance are critical determinants in transportation planning effectiveness. In corridor-dependent systems lacking alternative routes, limited connectivity tends to increase travel distances, increase reliance on specific links, and reduce network flexibility. This condition is also evident in the present study, where accessibility remains moderate to low (AI = 0.189) and travel times between activity centers still range from 90 to 111 minutes.

Therefore, both studies confirm that transportation networks characterized by corridor dependency and low connectivity indices tend to exhibit constrained accessibility, higher vulnerability to disruption, and reduced overall network effectiveness. This comparison reinforces the importance of developing additional linking roads and alternative routes to improve connectivity, reduce travel time, and enhance regional transportation resilience.

CONCLUSION

The transportation network of West Bangka Regency is structurally corridor-based and predominantly land-oriented, with 62 land vehicle facilities distributed across all sub-districts. In contrast, maritime facilities are concentrated in Mentok as the primary regional gateway. Mentok functions as the main transportation node, supported by a Type B terminal and a seaport directly connected to the national road network. However, spatial analysis reveals an uneven distribution of infrastructure, with higher road density in central and coastal areas and weaker connectivity in peripheral and rural zones. The transportation network of West Bangka Regency is structurally corridor-based and predominantly land-oriented, as shown in a graph comprising 12 links and 10 nodes that reflect the main inter-district road structure. Spatial and topological analysis indicates low structural connectivity, characterized by Beta values of 0.20–0.33, Gamma values of 0.08–0.13, negative Alpha indices, and a low road density of 0.039. These findings confirm that the network exhibits a linear and branching (tree-like) configuration with minimal redundancy and limited alternative routes, resulting in structural vulnerability and uneven connectivity, particularly between central and peripheral areas.

From an operational perspective, the network generally performs well under stable conditions, with V/C ratios ranging from 0.02 to 0.59 and Level of Service (LOS) ranging from A to C. However, the Accessibility Index value of 0.189 and travel times ranging from 90 to 111 minutes indicate moderate to relatively low accessibility, reflecting limited travel efficiency between activity centers. The integrated Network Effectiveness Index (NEI) places the system in a moderate effectiveness category, indicating that although operational performance remains stable, the network still has limited resilience and efficiency.

For policymakers, these findings highlight the need to prioritize the development of alternative, transversal road links to reduce dependence on single-corridor routes, improve inter-district accessibility, and enhance overall network resilience. Strengthening connections between peripheral and central areas should become a key infrastructure planning priority to support more balanced regional development. Furthermore, the integrated evaluation approach using connectivity, accessibility, and operational indicators provides a quantitative and practical framework for evidence-based transportation infrastructure planning, particularly in corridor-dominated developing regions.

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