

## Connectivity Index Approach for Evaluating Transportation Infrastructure in Bogor Regency, 2024

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### Abstract

This study evaluates the transportation infrastructure in Bogor Regency by employing a comprehensive Connectivity Index to assess the extent of integration across various transportation modes. The research aims to address pressing challenges, including limited accessibility, inadequate integration, and traffic congestion. Using data on road and rail networks and transportation nodes, three key indicators were analyzed: road-based public transport connectivity, rail-based transport coverage, and the integration of major transportation nodes. Results reveal that road-based connectivity stands at 33.55%, while rail-based connectivity ratio and integrated node percentage are at 0.052 km/km<sup>2</sup> and 17.02%, respectively. These findings highlight the suboptimal state of intermodal integration in Bogor Regency. The study concludes that targeted investments in rail network expansion and the development of multimodal transportation nodes are imperative. Enhanced integration and connectivity will support sustainable transportation systems, improve mobility, and foster economic development in the region.

### Abstrak

Penelitian ini mengevaluasi infrastruktur transportasi di Kabupaten Bogor dengan menggunakan Indeks Konektivitas yang komprehensif untuk menilai tingkat integrasi antar moda transportasi. Penelitian ini bertujuan untuk mengatasi tantangan utama, termasuk keterbatasan aksesibilitas, kurangnya integrasi, dan kemacetan lalu lintas. Dengan menggunakan data jaringan jalan dan rel serta simpul transportasi, tiga indikator utama dianalisis: konektivitas angkutan umum berbasis jalan, cakupan transportasi berbasis rel, dan integrasi simpul transportasi utama. Hasil menunjukkan bahwa konektivitas berbasis jalan berada pada angka 33,55%, rasio konektivitas berbasis rel sebesar 0,052 km/km<sup>2</sup>, dan persentase simpul terintegrasi sebesar 17,02%. Temuan ini menunjukkan bahwa integrasi antar moda di Kabupaten Bogor masih suboptimal. Penelitian ini menyimpulkan bahwa investasi terarah dalam perluasan jaringan rel dan pengembangan simpul transportasi multimoda sangat diperlukan. Peningkatan integrasi dan konektivitas akan mendukung sistem transportasi berkelanjutan, meningkatkan mobilitas, dan mendorong pengembangan ekonomi di wilayah tersebut.

## 1. Introduction

Effective and integrated transportation is a vital element in driving economic development while enhancing regional equity (Li et al., 2023; Upadhyay et al., 2023; Zhu, 2024). Bogor Regency faces complex transportation challenges, ranging from traffic congestion and limited accessibility to remote areas to a lack of integration between transportation modes (Ricardianto et al., 2023; Syaiful et al., 2023). These issues are exacerbated by rapid

urbanization and the expansion of new residential areas, underscoring the urgency of comprehensively evaluating the transportation system to support community mobility and economic activities (Samudra & Liong, 2023).

Globally, effective transportation connectivity has proven to be a key factor in enhancing regional competitiveness and improving people's quality of life (Gulyás & Kovács, 2016; Zuti, 2019). Bogor Regency, with its strategic position within the Greater Jakarta area (Jabodetabek), holds significant potential to become an efficient mobility hub. However, this potential can only be realized through an integrated and data-driven planning approach. Therefore, this study focuses not only on evaluating existing conditions but also on developing adaptive and visionary strategies to address future transportation challenges, particularly in supporting economic growth and equitable regional development.

This research concentrates on measuring and analyzing the level of transportation infrastructure connectivity in Bogor Regency as a foundation for data-driven policymaking. The evaluation aims to determine the extent to which the existing transportation network meets the community's needs optimally. Additionally, the study seeks to develop a Transportation Infrastructure Connectivity Index as a comprehensive evaluation tool and produce strategic recommendations that support planning based on Transit-Oriented Development (TOD) and the integration of transportation modes.

## 2. Research Methodology

This study employs several calculation approaches to gain an in-depth understanding of the current condition of the transportation system in Bogor Regency. The approaches are as follows:

### 2.1. Percentage of Road-Based Public Transport Connectivity

The measurement of the percentage of road-based public transport connectivity aims to assess the extent to which public transport services cover the road network in a given area, in this case, Bogor Regency. This indicator functions to identify the level of regional connectivity through public transport, which can serve as a basis for evaluating and developing a more effective and inclusive transportation system. This analysis is conducted using data on the length of public transport routes and the total road network length in the study area.

In this study, two primary data sources are utilized. The first is the length of public transport routes, specifically for angkot (minivans), obtained from the Ministry of Transportation in 2023. The second is the length of roads in Bogor Regency, derived from the Regional Spatial Planning (RTRW) document of Bogor Regency for the 2024–2044 period. These data serve as the foundation for analyzing and calculating the level of road-based public transport connectivity. The analysis results are determined using the following formula:

$$IKKI\ 1 = \frac{\text{Public Transport Route Length}}{\text{Total Road Length in Bogor Regency}} \times 100$$

This formula calculates the percentage of public transport route coverage compared to the total road length in Bogor Regency, providing an overview of the connectivity level of public transport services in the region. The results serve as a basis for the government to evaluate transportation effectiveness, identify underserved areas, and design policies for developing an inclusive and efficient transportation system. Periodic evaluations and data validation are necessary to ensure the reliability of this analysis, thereby supporting sustainable transportation planning that is responsive to community needs.

## 2.2. Ratio of Rail-Based Public Transport Connectivity

The measurement of the ratio of rail-based public transport connectivity aims to evaluate the extent to which rail transport services cover the area of Bogor Regency. This indicator serves to understand the presence and coverage of rail-based transportation services in supporting efficient community mobility while reducing reliance on road-based transport. This analysis uses two main data sources: the length of railway tracks obtained from the Regional Spatial Planning (RTRW) document of Bogor Regency for the 2024–2044 period and the total area of Bogor Regency as a reference. These data form the basis for evaluating the level of rail service connectivity in relation to the total area. The calculation of the rail-based connectivity ratio (IKKI2) is performed using the following formula:

$$\text{IKKI 2} = \frac{\text{Length of Urban Railway Tracks}}{\text{Total Area of Bogor Regency}}$$

The resulting value provides an overview of the level of rail transport connectivity in Bogor Regency. This information can be used to identify areas not yet served by rail services and to determine the need for network expansion. Additionally, this analysis aids local governments in designing better integration between rail-based and road-based transportation modes, thereby improving transportation efficiency and accessibility. Periodic evaluation of this indicator is essential to monitor the development of rail services and ensure that the data supports sustainable strategic decision-making.

## 2.3. Percentage of Integrated Major Transportation Nodes

The measurement of the percentage of integrated major transportation nodes aims to assess the connectivity level between primary transportation nodes, such as terminals, stations, and stops, and other feeder nodes. This indicator is essential for evaluating the integration of transportation modes, which plays a crucial role in enhancing the efficiency and convenience of public travel. Bogor Regency serves as a strategic location for applying this method, as well-integrated transportation nodes can support more effective community mobility. This analysis utilizes two primary data sources: the total number of transportation nodes in Bogor Regency, based on the Regional Spatial Planning (RTRW) document of Bogor Regency for the 2024–2044 period, and the number of integrated transportation nodes, obtained from BAPPEDA LITBANG in 2024. The percentage of integrated major transportation nodes is calculated using the following formula:

$$\text{IKKI 3} = \frac{\text{Number of Integrated Transportation Nodes}}{\text{Total Number of Transportation Nodes}} \times 100$$

This measurement serves as a basis for assessing the level of integration of major transportation nodes in Bogor Regency. The results are used to identify nodes that require further development to enhance the ease of intermodal transportation transfers. By increasing the number of integrated nodes, travel efficiency and convenience for the community can be improved. Periodic evaluation of these results ensures that transportation policies remain relevant to the needs and support the development of a more connected and sustainable transportation system.

## 2.4. Infrastructure Connectivity Index (Transportation)

The measurement of the Infrastructure Connectivity Index in the transportation sector is a method used to evaluate the extent to which transportation infrastructure in a region is well-connected. This indicator reflects the level of integration and connectivity of various transportation elements, such as road-based transport, rail-based transport, and transportation nodes. This evaluation is essential for understanding the effectiveness of the transportation system in supporting community mobility and travel efficiency. The formula for calculating the Transportation Infrastructure Connectivity Index is as follows:

$$IKIT = (30\% \times \frac{IKI1}{100}) + (30\% \times \frac{IKI2}{100}) + (40\% \times \frac{IKI3}{100})$$

Description:

IKK1 : Percentage of Road-Based Public Transport Connectivity

IKK2 : Ratio of Rail-Based Public Transport Connectivity

IKK3 : Percentage of Integrated Major Transportation Nodes

This index provides a comprehensive overview of the connectivity level of transportation infrastructure in a region. The calculation results can be used to identify transportation elements that require improvements to support a more efficient and integrated transportation system. Periodic evaluation of this index is crucial to ensure that transportation policies remain relevant to community needs and promote sustainable mobility.

## 3. Result and Discussion

### 3.1. Road-Based Public Transport Connectivity

Road-based public transport connectivity is an essential indicator for evaluating the extent to which public transport networks cover the available road infrastructure. This indicator reflects the level of public accessibility to transport services, which plays a crucial role in supporting daily mobility. Previous studies have shown that good connectivity contributes to reducing private vehicle use, increasing travel efficiency, and lowering carbon emissions (Newman & Kenworthy, 2015; Seredynski, 2023). The measurement of this connectivity forms the basis for determining sustainable transportation planning policies, particularly in Bogor Regency, a region experiencing high population growth. The values for each input are presented in Table 1.

Table 1. Input Values for Road-Based Public Transport Connectivity Parameters

No	Data	Road Length (km)
1	Length of Public Transport Routes (Angkot)	835
2	Total Road Length in Bogor Regency	2.488,53

Source: Perda Kabupaten Bogor No 1 Tahun 2024 tentang RTRW tahun 2024-2044

Based on calculations, the percentage of road-based public transport connectivity in Bogor Regency is 33.55%, indicating that public transport service coverage in the region is still limited. This figure shows that more than half of the roads in the area lack access to public transport services. An optimal connectivity value should be above 70%

to ensure equitable accessibility to public transportation. The low connectivity is likely caused by uneven route distribution, a limited number of transport operators, and road development priorities that focus more on private vehicles than on public transportation.

Additionally, other studies suggest that low route coverage can hinder efforts to reduce traffic congestion and increase dependence on private vehicles (Litman, 2015). This is particularly relevant in Bogor Regency, where the extensive rural areas necessitate more inclusive route policies. Therefore, expanding the public transport route network can be a strategy to improve connectivity, enabling transportation services to reach more people, especially in underserved areas.

Based on these findings, it is recommended that the Bogor Regency government integrate the development of public transport route networks into its transportation infrastructure development plans. This approach aligns with recommendations from various national and international studies emphasizing the importance of improving connectivity to support community mobility and environmental sustainability (Cervero & Kockelman, 1997; Dasgupta et al., 2021; Dewi & Krisdiyanto, 2023; Zafira & Puspitasari, 2022). Adding new routes and optimizing existing ones will help enhance road-based public transport connectivity, providing greater benefits to the community (Cervero et al., 2004). These efforts can also support traffic congestion reduction and carbon emission mitigation, in line with sustainable transportation goals.

### 3.2. Rail-Based Public Transport Connectivity

Rail-based public transport connectivity is an indicator that measures the extent to which rail transport services cover a given area. This indicator is crucial for assessing the efficiency and coverage of rail-based transportation services, which act as the backbone of the mass transportation system. Studies have shown that well-developed rail transport systems can integrate urban and rural areas, enhance the efficiency of community mobility, and reduce reliance on private vehicles (Cervero & Murakami, 2009). Evaluating this connectivity is vital to support the transportation system in Bogor Regency, which spans a large area and has increasing mobility needs. The input values used to calculate rail-based public transport connectivity are provided in Table 2, and the details of railway lengths are presented in Table 3.

Table 2. Input Values for Rail-Based Public Transport Connectivity Parameters

No	Data	Unit	Value
1	Length of Railway Tracks	Km	156,27
2	Luas Wilayah Kabupaten Bogor	Km <sup>2</sup>	2.991,78

Source: Perda Kabupaten Bogor No 1 Tahun 2024 tentang RTRW tahun 2024-2044

Table 3. Details of Railway Track Length

No	Railway Network / Line Name	Length (km)		
		Existing	Plan	Total
	<b>Intercity Railway Network</b>	<b>12,67</b>	<b>41,54</b>	<b>54,21</b>
1	Cileungsi - Jonggol - Cianjur		41,54	41,54
2	Kota Bogor - Sukabumi - Bandung - Yogyakarta	12,67		12,67
	<b>Urban Railway Network</b>	<b>36,61</b>	<b>65,45</b>	<b>102,06</b>

3	Angke – Merak	12,35		12,35
4	Jakarta-Bogor	11,36		11,36
5	Loop Line Bogor Raya		4,28	4,28
6	LRT Cibubur-Bogor		21,38	21,38
7	Nambo-Cikarang-Tanjung Priok		18,31	18,31
8	Nambo-Citayam	12,90		12,90
9	Parungpanjang – Citayam		21,47	21,47
	<b>Total Length</b>	<b>49,28</b>	<b>106,99</b>	<b>156,27</b>

Source: Perda Kabupaten Bogor No 1 Tahun 2024 tentang RTRW tahun 2024-2044

The calculation yields a rail-based public transport connectivity ratio of 0.052 km/km<sup>2</sup>, indicating that for every square kilometer of Bogor Regency, there is approximately 0.052 km of railway network. This relatively low ratio highlights the limited coverage of the railway network in the region. A connectivity ratio of 0.052 km/km<sup>2</sup> suggests that the rail transport system is suboptimal in meeting the mobility needs of the population (Givoni & Banister, 2010), particularly in a large area like Bogor Regency. Other studies emphasize that expanding the railway network and integrating it with other transport modes can enhance accessibility, reduce traffic congestion, and accelerate economic growth in the region (Bertolini et al., 2005).

The low connectivity value can be attributed to factors such as limited investment in new railway construction, geographical constraints, and infrastructure development priorities that focus more on road-based transportation. Collaborative efforts between the central and regional governments are necessary to improve rail transport infrastructure to meet the increasingly complex mobility needs of the population.

The analysis results indicate that the railway connectivity ratio in Bogor Regency requires improvement to optimally support community mobility. Strategic initiatives such as constructing new railway lines, extending existing lines, and integrating them with other transport modes should be prioritized. Developing a well-planned rail-based transport system will support a more efficient, environmentally friendly, and sustainable transportation network. These measures will enable Bogor Regency to establish a transportation system that better meets the needs of its residents.

### 3.3. Integrated Major Transportation Nodes

Integrated major transportation nodes are an indicator that reflects the extent to which primary transportation hubs, such as terminals, stations, and stops, are connected with other transport modes to support efficient intermodal transfers. This integration is essential for creating a coordinated transportation system, facilitating community mobility, and reducing travel time and costs. Research shows that integrated transportation nodes can improve the efficiency of transport networks and encourage greater use of public transport (Bertolini et al., 2005). Evaluating the situation in Bogor Regency is a crucial step in identifying potential improvements for the integration of transportation nodes. Below are the input values used to calculate the percentage of integrated major transportation nodes (Table 4).

Table 4. Input Values for the Percentage of Integrated Major Transportation Nodes

No	Data	Jumlah
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1	Total Number of Major Transportation Nodes	47
2	Number of Integrated Transportation Nodes	8

Source: Perda Kabupaten Bogor No 1 Tahun 2024 tentang RTRW tahun 2024-2044 and BAPPEDA LITBANG Kabupaten Bogor tahun 2024

The results show that only 17.02% of major transportation nodes in Bogor Regency are integrated. This indicates that most transportation nodes in the region lack adequate connections with other transport modes. Such low integration levels can hinder the creation of an efficient and inclusive transportation system. The limited integration of transportation nodes may lead to a greater dependence on private vehicles, resulting in increased traffic congestion and carbon emissions (Litman, 2015).

Several factors contribute to the low integration value, including the lack of supporting infrastructure such as pedestrian pathways, limited intermodal connection facilities, and insufficient coordination in transportation planning. Research emphasizes the importance of transportation integration through the development of transportation nodes designed to support seamless and convenient intermodal transfers (Susantono, 2013).

These findings highlight that Bogor Regency requires significant efforts to enhance the integration of its major transportation nodes. Local governments need to adopt strategies to increase the number of integrated transportation nodes, such as building supporting infrastructure and improving intermodal connection facilities. These steps underline the importance of integration in creating a transportation system that is efficient, environmentally friendly, and supportive of community mobility. With these efforts, the percentage of integrated nodes is expected to increase, thereby improving community mobility and fostering regional economic growth.

### 3.4. Transportation Infrastructure Connectivity Index (TICI)

The Transportation Infrastructure Connectivity Index (TICI) is an indicator that reflects the level of connectivity and integration between different transportation modes in a region. Evaluating TICI is crucial for assessing the sustainability and efficiency of the transportation system in supporting community mobility and economic activities (Ayadi et al., 2024; Macheret & Razuvaev, 2024; Miano et al., 2024). According to Bogor Regent Regulation No. 6 of 2023 on the Bogor Regency Transportation Master Plan, integrated transportation is one of the main pillars for creating an efficient, environmentally friendly, and competitive system.

Table 5. Values of Transportation Infrastructure Connectivity Index Parameters

No	Parameter	Nilai
1	Percentage of Road-Based Public Transport Connectivity	33,55%
2	Ratio of Rail-Based Public Transport Connectivity	0,05
3	Percentage of Integrated Major Transportation Nodes	17,02%

Based on the calculation, the Urban Transportation Infrastructure Connectivity Index (TICI) for Bogor Regency is 0.18. This TICI value reflects significant limitations in Bogor Regency's transportation system, particularly in intermodal integration. It is strongly influenced by the low values of two main parameters: the rail-based connectivity ratio (0.05) and the percentage of integrated transportation nodes (17.02%). The low rail-based connectivity ratio indicates that the railway network has not adequately covered Bogor Regency. Meanwhile, the

low percentage of integrated nodes highlights the lack of intermodal connection facilities, such as integrated terminals or sufficient intermodal access points.

The relatively higher percentage of road-based public transport connectivity (33.55%) demonstrates the dominant role of road-based modes in Bogor Regency's transportation system (Table 5). However, this dominance is not complemented by integration with other modes, thus affecting the overall TICI value. Low transportation infrastructure connectivity can lead to limited public accessibility to transport services, increased dependence on private vehicles, and negative environmental impacts such as pollution and congestion (Litman, 2015).

The TICI value of 0.18 emphasizes the need for significant improvements in Bogor Regency's transportation system, particularly in developing the rail network and integrating transportation nodes. The Bogor Regency government can prioritize investments in developing integrated transportation nodes, such as multimodal terminals and intermodal transfer facilities, to improve intermodal connectivity. With these strategic measures, the TICI value can be enhanced, supporting community mobility and creating a more efficient, integrated, and sustainable transportation system.

#### 4. Conclusion

The evaluation of transportation connectivity in Bogor Regency reveals significant challenges in integrating and optimizing transportation infrastructure. The findings indicate limitations in the connectivity of road-based public transport, rail networks, and major transportation nodes, which impact community mobility and economic activities. The calculated Transportation Infrastructure Connectivity Index (TICI) reflects these constraints, underscoring the need for targeted investments in expanding rail networks, optimizing public transport routes, and enhancing the integration of transportation nodes. Strategic efforts focused on improving connectivity and promoting sustainable transportation systems are essential to address these challenges and support the region's long-term development goals.

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