

# Density by Design: Evaluating Transit Hubs for Transit-Oriented Development (TOD) in an Emerging Indonesian Metropolis

Haratama, K.R.<sup>1\*</sup>, Farizi, A.M.A.<sup>1</sup>, Saputro, M.C.<sup>1</sup>, Manggalasari, L.C.<sup>2</sup>, and Thipphaya, P.<sup>3</sup>

<sup>1</sup> Department of Transportation Engineering, State University of Surabaya, INDONESIA

<sup>2</sup> Department of Public Administration, State University of Surabaya, INDONESIA

<sup>3</sup> Department of Local Governance, Khon Kaen University, THAILAND

DOI: <https://doi.org/10.9744/ced.28.1.54-68>

## Article Info:

Submitted: June 26, 2025

Reviewed: July 12, 2025

Accepted: Dec 17, 2025

## Keywords:

accessibility,  
built environment index,  
land use mix,  
population density,  
transit-oriented development.

## Corresponding Author:

**Haratama, K.R.**

Department of Transportation Engineering,  
State University of Surabaya,  
INDONESIA

Email: [kusumaharatama@unesa.ac.id](mailto:kusumaharatama@unesa.ac.id)

## Abstract

Rapid urbanization in Indonesian cities has increased interest in Transit-Oriented Development (TOD) as a strategy to promote compact, mixed-use, and transit-supportive urban forms. This study evaluates the TOD readiness of five major transit hubs in Surabaya—Purabaya Terminal, Joyoboyo Terminal, Gubeng Station, Surabaya Kota Station, and Pasar Turi Station—using a spatially explicit Built Environment Index (BEI). A Geographic Information System (GIS) approach was applied to analyze population density, employment density, land use mix, and accessibility within 400, 800, and 1,200 m service areas. These indicators were normalized and aggregated into the BEI under multiple weighting scenarios to reflect different planning priorities. The results identify Gubeng Station as the most TOD-ready hub, supported by high density, balanced job-to-population ratio, and strong land use integration, while Joyoboyo and Pasar Turi show limited TOD alignment. The proposed framework provides a replicable, data-driven tool to support TOD prioritization in emerging metropolitan contexts.

*This is an open access article under the [CC BY](https://creativecommons.org/licenses/by/4.0/) license.*



## INTRODUCTION

The disciplines of urban and transportation planning struggle with the multifaceted challenges of accommodating rapid urbanization while fostering sustainable and equitable communities [1]. Urban sprawl, characterized by low-density development and dispersed land uses, exacerbates traffic congestion, increases reliance on private vehicles, and contributes to environmental degradation, thereby diminishing the overall quality of life for urban dwellers [2]. The escalating demand for mobility in growing metropolitan areas often surpasses the capacity of existing transportation infrastructure, resulting in gridlock, delays, and economic inefficiencies. In response to these pressing concerns, Transit-Oriented Development (TOD) has emerged as a globally recognized urban planning strategy that aims to promote compact, mixed-use development patterns that are centered around high-quality public transportation systems [3]. TOD seeks to integrate land use and transportation planning to create walkable, bikeable, and transit-supportive environments that reduce car dependency, promote sustainable transportation choices, and enhance accessibility to jobs, housing, and services [4]. Empirical studies in Indonesian cities indicate that travel-cost/time elasticities and commuting patterns respond strongly to local built environment attributes, underscoring the importance of density and land-use mix for transit ridership [5]. By concentrating development around transit hubs, TOD can foster vibrant, mixed-income communities, reduce greenhouse gas emissions, and improve overall urban sustainability [6].

**Note** : Discussion is expected before July, 1<sup>st</sup> 2026, and will be published in the "Civil Engineering Dimension", volume 28, number 2, September 2026.

**ISSN** : 1410-9530 print / 1979-570X online

**Published by** : Petra Christian University

Built environment indicators, such as population density, employment density, land use mix, and street network design, are crucial in assessing the potential for successful TOD implementation and measuring its impacts on travel behavior and urban form [7]. Population density, measured as the number of residents per unit area, is a key determinant of transit ridership, as higher densities generate greater demand for public transportation services and make transit investments more economically viable. Employment density, defined as the number of jobs per unit area, is another critical factor influencing transit demand, particularly during peak commuting hours, and contributes to the economic vitality of transit-oriented districts. Mixed land use, characterized by the integration of residential, commercial, and institutional uses within close proximity, enhances walkability, reduces trip lengths, and promotes the use of public transportation by providing residents and workers with access to various destinations within a short distance. Spatial analysis techniques, employing Geographic Information Systems, provide powerful tools for evaluating service areas around transit hubs, assessing the distribution of population and employment, and identifying opportunities for infill development and transit-supportive land use policies. These methods enable planners to visualize and quantify the spatial relationships between transit infrastructure and the surrounding built environment, allowing for data-driven decision-making and targeted interventions to promote TOD principles [8]. As a rapidly urbanizing city in Indonesia, Surabaya is beginning to adopt TOD strategies to address its growing transportation challenges and promote sustainable urban development [9,10]. By strategically locating higher-density residential and commercial development around transit stations, Surabaya aims to reduce traffic congestion, improve air quality, and create more livable and accessible neighborhoods.

Despite the growing recognition of TOD as a sustainable urban development strategy, spatially detailed assessments of TOD readiness in cities like Surabaya remain insufficient, particularly in developing contexts. While policymakers and practitioners widely promote TOD, a limited number of comparative, indicator-based evaluations of transit hub performance consider the unique socio-economic and spatial characteristics of developing cities. Many existing studies focus on developed countries and may not be directly applicable to the context of rapidly urbanizing cities in Southeast Asia, which often face different challenges related to land use regulation, infrastructure provision, and informal sector activities. Commonly used frameworks include the TOD Standard developed by the Institute for Transportation and Development Policy (ITDP), which scores urban environments based on proximity, connectivity, density, and diversity criteria; the TOD Scorecard by Cervero [11], which focuses on accessibility, land use mix, and transit service quality; and accessibility-based evaluations grounded in the “5Ds” framework—density, diversity, design, destination accessibility, and distance to transit. Other approaches rely on Multi-Criteria Decision Analysis (MCDA) to integrate socioeconomic, spatial, and transport-related indicators into a single assessment [12]. While these methods are comprehensive, they often require extensive datasets, complex weighting schemes, or qualitative assessments that may limit their replicability in data-constrained contexts.

This study addresses the aforementioned gaps by evaluating five major transit hubs in Surabaya (Purabaya Terminal, Joyoboyo Terminal, Gubeng Station, Surabaya Kota Station, and Pasar Turi Station) using a comprehensive GIS-based Built Environment Index (BEI) analysis framework, incorporating detailed population and employment data and land use metrics [13]. The BEI was selected as the evaluation method because it offers a quantitative, spatially explicit, and adaptable framework that integrates multiple TOD-relevant indicators, namely population density, employment density, land use mix, and accessibility, into a single comparable score [14]. The BEI is particularly suitable for GIS-based analysis and for comparing multiple transit hubs within the same urban area, enabling a consistent and objective assessment that aligns with both the study’s data availability and research objectives [15]. Therefore, the research aims to provide insights into the spatial distribution of population and employment densities around transit stations, assess the mix of land uses, and identify areas with the greatest potential for TOD implementation. By employing a data-driven approach, the study seeks to inform urban planning policies and investment decisions related to transit-oriented development in Surabaya and other similar cities in the developing world. The study's findings suggest that, among the transit hubs evaluated, Gubeng Station emerges as the most suitable for TOD, demonstrating the potential replicability of the applied method for similar urban contexts globally.

## METHODS

The methodological framework employed in this study leverages spatial analysis techniques to evaluate population and employment density characteristics within the sphere of influence of major transit hubs in Surabaya, Indonesia, thereby providing empirical evidence for assessing the extent to which existing development patterns align with the principles of Transit-Oriented Development.

### Research Process Overview

This study followed a structured process to evaluate the Transit-Oriented Development (TOD) readiness of five major transit hubs in Surabaya: Surabaya Terminal, Joyoboyo Terminal, Gubeng Station, Surabaya Kota Station, and Pasar

Turi Station (Figure 1). The process began with the identification of the hubs as key nodes in the city's transport network, representing both bus and rail-based transit services that facilitate the movement of commuters and goods across the metropolitan region and beyond [16]. Each hub was then assigned three service area thresholds of 400, 800, and 1,200 meters, which reflect standard walking and biking distances and enable the measurement of TOD-supportive conditions at varying spatial scales [3,17,18].

The next stage involved data preparation, in which population density, employment density, and land use composition were collected from official statistical and spatial sources, including OpenStreetMap for detailed road network information, Google Satellite imagery for visual context and land cover assessment, BPS (Agency of Statistics Indonesia) for granular population statistics at the administrative level, ATR/BPN (Ministry of Agrarian Affairs and Spatial Planning/National Land Agency of Indonesia *Kementerian Agraria dan Tata Ruang/Badan Pertanahan Nasional*) datasets for delineating land use zones, and Google Maps for capturing the spatial distribution of employment centers and points of interest, ensuring a comprehensive and reliable foundation for subsequent analyses [19]. These data were processed using Geographic Information Systems (GIS) to calculate indicator values for each service area buffer. Population and employment densities were expressed as the number of people or jobs per square kilometer, while land use mix was represented through the balance between residential and commercial functions.

The final stage of the process integrated these indicators into a BEI, which serves as a composite measure of TOD readiness. The BEI was calculated under multiple weighting scenarios to test the sensitivity of results toward different planning priorities, such as population-focused or employment-focused development. This multi-scenario evaluation allowed for a more robust comparison of hubs and provided insights into the strengths and weaknesses of each location.

Overall, this research process combines spatial analysis, indicator-based assessment, and composite indexing to create a consistent and replicable framework for evaluating TOD potential at the hub level. The subsequent sections describe the technical details of service area delineation, density calculations, land use analysis, and BEI construction.



**Figure 1.** Location of the Five Major Hubs in Surabaya

### Population Density Analysis

The population density analysis within the defined service areas involved overlaying the service area polygons with administrative boundary data containing population statistics obtained from BPS, enabling the calculation of population figures for each buffer radius around the transit hubs. This process entailed calculating the proportion of each administrative unit's area that fell within each buffer zone, as shown in Equation (1), and then applying this proportion to the population count of that unit, as shown in Equation (2), to estimate the population residing within the buffer zone. Population density was then calculated using Equation (3) by dividing the estimated population within each buffer zone by the area of the buffer zone, providing a standardized metric for comparing population concentrations across different transit hubs and buffer distances.

$$\%_{SA} = \left( \frac{SA_{Sub}}{A_{Sub}} \right) \times 100\% \quad (1)$$

$$P_{SA} = \left( \frac{\%_{SA}}{100} \right) \times P_{Sub} \quad (2)$$

$$DP = \left( \frac{P_{SA}}{SA} \right) \quad (3)$$

Where:

$\%_{SA}$  = percentage of service area

$SA_{Sub}$  = service area per sub-district (km<sup>2</sup>)

$A_{Sub}$  = total area of sub-district (km<sup>2</sup>)

$P_{SA}$  = population in the service area – per threshold (people)

$P_{Sub}$  = total population in the sub-district (people)

$DP$  = population density (people/km<sup>2</sup>)

$SA$  = service area – per threshold (km<sup>2</sup>)

### Employment Density Analysis

Complementing the population density analysis, employment density was assessed to understand the spatial distribution of employment opportunities around the transit hubs. To achieve this, location data of businesses and points of interest were gathered from Google Maps using web scraping techniques, capturing information on business names, addresses, and categories. This data was then categorized into different employment sectors, such as retail, services, and offices, and estimates of employment per point of interest were derived based on the type and size of the business. Employment density was estimated by translating commercial land use area into a potential workplace capacity. A benchmark of 10 m<sup>2</sup> per worker was applied, which aligns with international workplace planning standards [20,21] and is consistent with Presidential Regulation No. 73 of 2011, Articles 6–9, which sets minimum floor area standards for workplace planning in Indonesia. This regulatory benchmark has also been used in other urban planning studies as a proxy for estimating job capacity in data-scarce contexts. It is acknowledged, however, that not all commercial space is actively occupied or utilized for employment purposes. Vacancies, circulation areas, or storage space may reduce effective density, while certain high-intensity uses such as retail or workshops may accommodate more workers than the standard suggests. To address this, the 10 m<sup>2</sup> standard was applied uniformly across all hubs, ensuring comparability in the analysis. The resulting employment density values should therefore be interpreted as indicative of relative differences between hubs rather than exact job counts. Future research could refine this approach by incorporating land use surveys or detailed employment datasets to capture actual workplace occupancy. The estimated employment figures were then aggregated within each buffer zone using Equation (4), and employment density was calculated by dividing the total employment within each buffer zone by the area of the buffer zone using Equations (5) and (6).

$$n_w = \frac{A}{10} \quad (4)$$

$$DE = \frac{N_w}{SA} \quad (5)$$

$$N_w \begin{cases} \sum n_w(R_{0-400}), & \text{if } d \leq 400 \\ \sum n_w(R_{400-800}), & \text{if } 400 < d \leq 800 \\ \sum n_w(R_{800-1200}), & \text{if } 800 < d \leq 1200 \end{cases} \quad (6)$$

Where:

$n_w$  = estimated workers per business (people)

$A$  = area of the business building (m<sup>2</sup>)

$DE$  = employment density (people/km<sup>2</sup>)

$N_w$  = total of estimated workers within a specific threshold ( $\sum n_w$ ) (people)

$SA$  = service area per threshold (km<sup>2</sup>)

$R_{x-y}$  = ring or threshold

In this study,  $N_w$  represents the sum of all  $n_w$  within a defined service threshold, ensuring that employment estimates reflect the total workforce accessible at different distances from the hub.  $R_{x-y}$  denotes the area of land use polygons located within the radial distance between  $x$  and  $y$  meters from the transit hub. For instance,  $(R_{0-400})$  refers to the area enclosed within the 400-meter buffer,  $(R_{400-800})$  refers to the ring between 400 and 800 meters, and so forth.

### Land Use Composition Analysis

A land use composition analysis was performed to gain insights into the mix of land uses within the service areas, classifying land use into three broad categories: residential, commercial, and mixed-use, based on the ATRBPN land use data and visual interpretation of satellite imagery. The proportion of each land use category within each service area was then calculated using Equation (7), providing a quantitative measure of the land use mix around each transit hub and allowing for comparisons across different locations.

$$\%_{LU} = \left(\frac{a}{A}\right) \times 100\% \quad (7)$$

Where:

$\%_{LU}$  = percentage of land use (category land)

$a$  = category land area (km<sup>2</sup>)

$A$  = total area (km<sup>2</sup>)

### BEI Calculation

The BEI was developed as a composite measure to evaluate TOD readiness at the transit hub level by integrating multiple built environment attributes into a single score [22]. Composite indices are widely used in urban and transport studies to operationalize multidimensional concepts such as walkability, accessibility, and TOD-supportive urban form [23,24]. BEI was calculated to capture the key dimensions of density, diversity, and design that are considered essential for successful TOD implementation using Equations (8) and (9). Prior to calculating the BEI, the indicator values were normalized using min-max normalization, scaling the values between 0 and 1 to ensure comparability across different indicators with varying units and scales as shown in Equation (10). The design of urban spaces should consider non-motorized mobility [10]. The normalized indicator values were then combined using a weighted scoring approach, reflecting the relative importance of each indicator in contributing to TOD outcomes, allowing for the ranking of different transit hubs based on their overall built environment characteristics. In this study, the BEI incorporates four components:

- Population Density (PD) – residents per km<sup>2</sup> within service areas, representing residential intensity and potential ridership base.
- Employment Density (ED) – estimated jobs per km<sup>2</sup>, representing workplace concentration and destination strength.
- Job-to-population Ratio - the proportion of working-age population that is currently employed per km<sup>2</sup>.
- Land Use Mix (LUM) – degree of balance between residential and commercial land uses, indicating functional diversity and accessibility.

Let  $K$  denote the number of component indicators included in the BEI (here  $K = 4$ ). For hub  $i$  and a given weighting scenario  $s$ , the BEI is computed as the weighted linear combination of the normalized indicator scores:

$$BEI_i^{(s)} = \sum_{k=1}^K w_k^{(s)} \cdot X'_{ik} \quad (8)$$

subject to:

$$\sum_{k=1}^K w_k^{(s)} = 1, \quad 0 \leq w_k^{(s)} \leq 1 \quad (9)$$

Where:

$BEI_i^{(s)}$  = Built Environment Index score for hub  $i$  ( $i = 1$  to  $n$  hubs)

$w_k^{(s)}$  = the weight assigned to indicator  $k$  under scenario  $s$ . Different scenarios (equal, population-focused, employment-focused, mixed-use, etc.) correspond to different weight vectors  $\{w_k^{(s)}\}_{k=1}^K$ .

$X'_{ik}$  = the normalized value of indicator  $k$  for hubs

$$X'_{ik} = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (10)$$

Where:

$X'_{ik}$  = normalized value

$X$  = targeted value

$X_{min}$  = minimum value

$X_{max}$  = maximum value

To ensure robustness, the BEI was calculated under multiple weighting scenarios. An equal-weight scenario ( $w = 0.25$  for each factor) was first applied to provide a neutral benchmark and to avoid favoring any single indicator. Beyond this, weights were varied between 0.35 and 0.75 to simulate policy priorities. For example, a population-focused scenario assigned a higher weight to population density ( $w = 0.5$ ) while reducing others proportionally. Similarly, employment-focused or land-use-focused scenarios emphasized their respective indicators. These scenarios do not undermine the concept of BEI; instead, they provide a structured sensitivity analysis that examines how different policy emphases (e.g., housing-led growth vs. job-led growth) affect hub rankings. This framework ensures that the BEI is not simply a summation of indicators but a flexible evaluation tool responsive to planning hypotheses.

The weighting choices also acknowledge that different transit hub types (e.g., rail stations versus bus terminals) serve distinct roles within the urban system. For instance, a bus terminal such as Purabaya may be better assessed under employment-focused scenarios, since it functions as both a transit gateway and a workplace node [12]. In contrast, rail stations embedded in dense neighborhoods, such as Gubeng, are more aligned with population- or land-use-focused weighting [25]. By comparing BEI results across weighting schemes, the analysis provides insights not only into hub performance but also into which planning priorities each hub is most compatible with.

Overall, this multi-scenario weighting framework strengthens the BEI's explanatory power. It allows for hypothesis testing regarding TOD suitability under different urban development logics, ensures comparability across hub types, and highlights where planning interventions could be targeted most effectively.

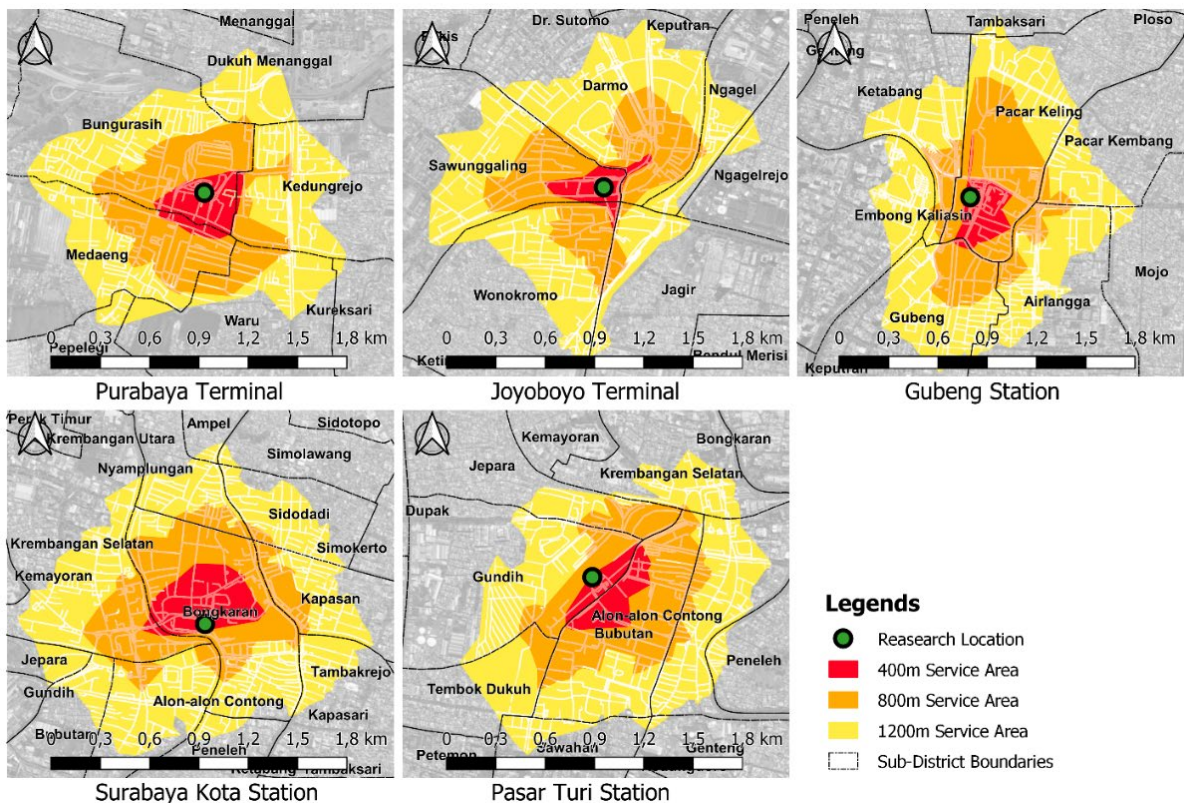
## RESULTS AND DISCUSSION

### Service Area Coverage

The evaluation of service area coverage in Surabaya, as derived from the spatial analysis of walkable and bikeable catchments around transit hubs (Figure 2), provides critical insights into the city's potential for successful transit-oriented development [26]. The observed variations in service area coverage across the five transit hubs—Purabaya Terminal, Joyoboyo Terminal, Gubeng Station, Surabaya Kota Station, and Pasar Turi Station—, as mentioned in Table 1, highlight the intricate relationship between urban morphology, road network connectivity, and the accessibility of transit facilities, which directly influences the viability of TOD principles [27]. The higher accessibility values recorded for Surabaya Kota and Gubeng Stations suggest a well-integrated urban fabric characterized by permeable street networks that facilitate pedestrian and bicycle movement, aligning with the core principles of TOD that emphasize seamless multimodal access [8]. The consistent growth pattern observed at Gubeng Station, indicative of a grid or semi-grid road network, reinforces the importance of network structure in maximizing service area coverage and promoting sustainable transportation modes. Conversely, the lower accessibility values associated with Joyoboyo Terminal underscore the challenges posed by fragmented suburban road patterns, which impede permeability and limit the catchment area that the transit hub can effectively serve; this disparity points to the necessity of strategic interventions to improve connectivity and promote compact, mixed-use development in the terminal's surrounding areas. Referring to the typologies illustrated in the Street Network Disconnectedness Index (SNDI) diagram (Figure 3), this comparison allows for a theory-informed interpretation of service area performance, as the street patterns around Surabaya's transit hubs—such as the grid-like structure near Gubeng Station or the more dendritic, disconnected layout near Joyoboyo Terminal—clearly correlate with differences in catchment coverage and pedestrian accessibility. Recent evidence shows that higher intersection/road densities affect not only accessibility but also traffic and pedestrian safety outcomes, which TOD planning should explicitly consider [28].

The distinctive growth pattern exhibited by Purabaya Terminal, characterized by moderate initial growth followed by a steep increase at larger distances, refers to a spatial configuration where access to the inner core is constrained,

while connectivity to the outer areas is more robust, which can be attributed to the terminal's location on the periphery of the city center, where road networks may be less dense and more focused on vehicular traffic. In comparison, Surabaya Kota Station's superior network integration reflects the inherent advantages of historic urban cores or mixed-use districts, where fine-grained street networks and a diverse range of land uses promote walkability and reduce dependence on private vehicles, thereby enhancing the station's accessibility and its potential to catalyze TOD. While demonstrating reasonably good connectivity, Pasar Turi Station exhibits slightly lower service coverage than the top performers, indicating potential areas for improvement in terms of pedestrian infrastructure and integration with surrounding land uses to achieve optimal TOD outcomes. These findings resonate with established urban morphology and road network connectivity theories, which postulate that fine-grained, permeable street grids are fundamental to achieving higher service area accessibility and fostering sustainable urban environments [30].

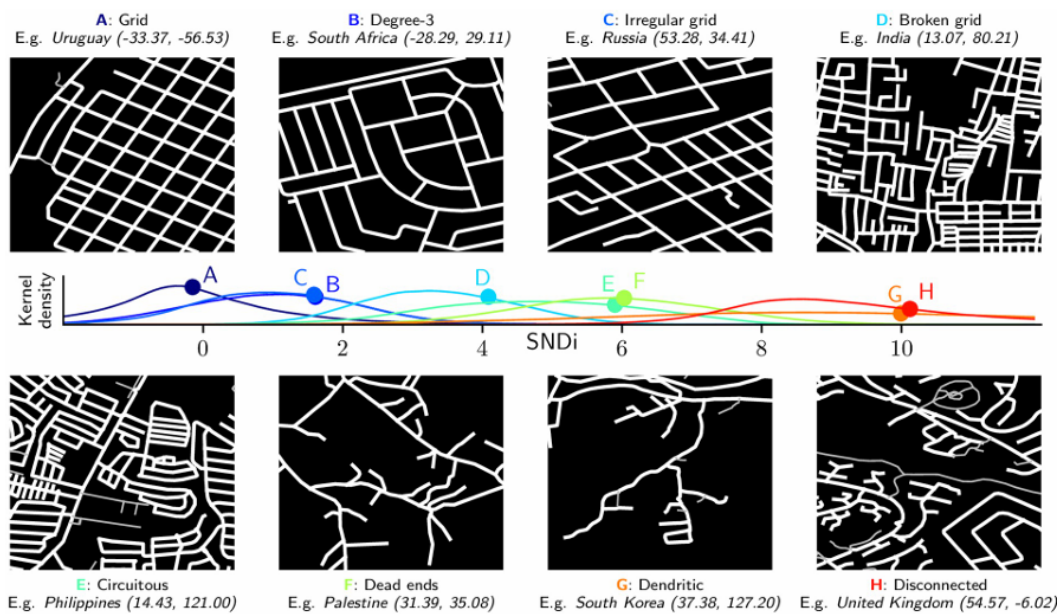


**Figure 2.** Pedestrian and Cycling Service Areas of the Five Major Transit Hubs in Surabaya, delineated by 400 m (red), 800 m (orange), and 1,200 m (yellow) Buffers. These Areas Reflect the Spatial Reach and Local Accessibility of Each Hub, overlaid on Sub-District Boundaries for Contextual Analysis

**Table 1.** Service Area Coverage for Every Threshold (km<sup>2</sup>)

Hubs	400-meter	800-meter	1,200-meter
Purabaya Terminal	0.147	0.790	2.060
Joyoboyo Terminal	0.078	0.663	2.040
Gubeng Station	0.104	0.741	2.320
Surabaya Kota Station	0.208*	0.906*	2.424*
Pasar Turi Station	0.151	0.798	2.140

The observed disparities in service area coverage across Surabaya’s transit hubs highlight the critical role of road network structure in shaping the accessibility and effectiveness of transit-oriented development (TOD). TOD offers a development pattern centered on transit nodes in densely populated areas, providing an alternative to conventional suburban layouts that prioritize automobiles and result in disconnected environments [2,13,31]. Prioritizing well-connected street networks is essential for creating pedestrian- and bicycle-friendly environments, which are key to supporting active transportation and enhancing access to transit facilities [32]. Improving road connectivity is thus a foundational element of TOD, particularly in dense urban contexts where enhanced access can significantly reduce car dependency. Moreover, appropriate urban design and planning around public transport can offer local and regional mobility solutions that minimize automobile reliance [10]. These insights emphasize that successful TOD implementation requires careful attention to the design and permeability of road networks, enabling walkable, accessible communities that support sustainable and equitable urban mobility [33].



**Figure 3.** Road Network Typologies across the Street Network Disconnectedness Index (SNDi), Illustrating Varying Degrees of Connectivity and Implications for Walkable and Bikeable Catchment Areas Around Transit Hubs (adapted from [29])

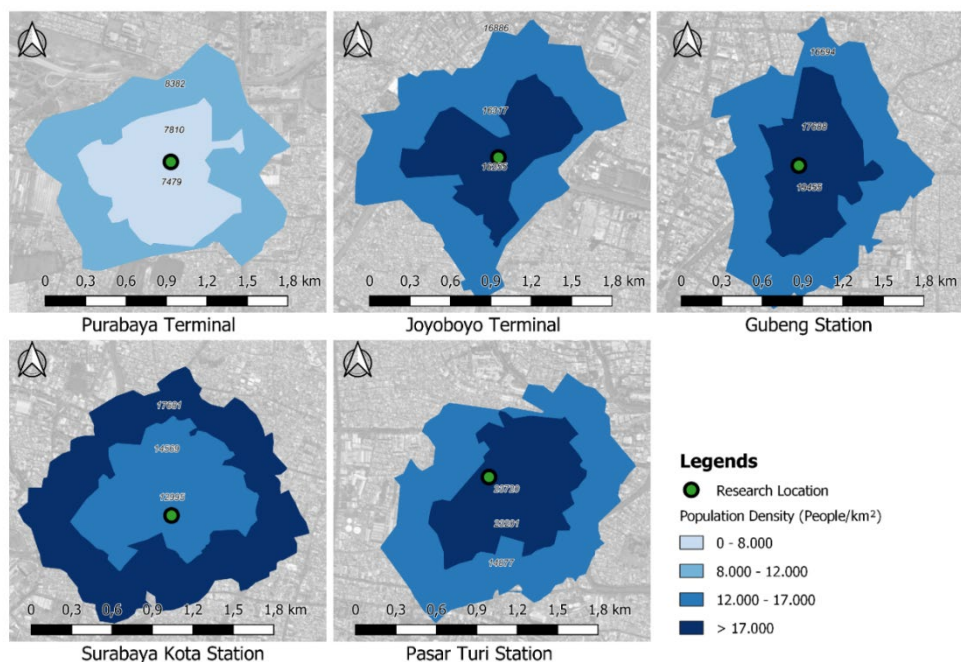
### Population and Employment Density

Population and employment density stand as pivotal determinants in the efficacy of Transit-Oriented Development, serving as barometers not only for gauging the prospective demand for public transport infrastructure but also for assessing the degree of synergistic integration within the urban milieu [8]. A quintessential TOD-aligned ecosystem is characterized by elevated population densities proximal to transit nodes, interwoven with a harmonious equilibrium between employment opportunities and residential dwellings, thereby fostering heightened walkability indices and curtailing vehicular dependence predicated on protracted commutes [30]. In the context of Surabaya, a thorough investigation into the population and employment densities surrounding its primary transit hubs - namely, Purabaya Terminal, Joyoboyo Terminal, Gubeng Station, Surabaya Kota Station, and Pasar Turi Station—unveils a tapestry of heterogeneous profiles, each bearing distinctive implications for the application and optimization of TOD principles within the local urban framework. The strategic co-location of residential, commercial, and recreational amenities within walking distance of transit facilities not only amplifies ridership but also cultivates vibrant, mixed-use communities that are less reliant on private automobiles, thereby mitigating congestion and promoting environmental sustainability [2]. The juxtaposition of population and employment densities around transit nodes serves as a crucial indicator of the functional integration and self-sufficiency of these areas, influencing commuting patterns, land use dynamics, and the overall quality of life for residents [19]. The challenges encountered by areas adopting TOD principles highlight the necessity of understanding local context and important elements of area development [3].

Gubeng Station stands out as the most TOD-ready hub, exhibiting a high peak population density at 400 m (19,455 people/km<sup>2</sup>), as illustrated in Figure 4, and a well-balanced job-to-population ratio of 1.01 (Figure 5). This suggests a strong residential concentration immediately around the station and sufficient employment opportunities to support daytime activity and reduce commuting distance. The declining density outward from the hub aligns well with TOD principles, emphasizing compact, walkable urban cores with high land use intensity near transit access points. Pasar Turi Station demonstrates the highest overall population densities in the 400 m and 800 m zones (23,720 and 23,201 people/km<sup>2</sup>, respectively), reflecting a compact, high-density urban form that supports transit ridership. However, its job-to-population ratio of 0.62 reveals a predominance of residential land use with fewer local employment opportunities. While this can result in strong ridership potential, the lack of employment limits its capacity to function as a fully integrated, mixed-use TOD area. The sharp density drop at 1,200 m may also reflect physical barriers or land use zoning transitions that inhibit broader integration.

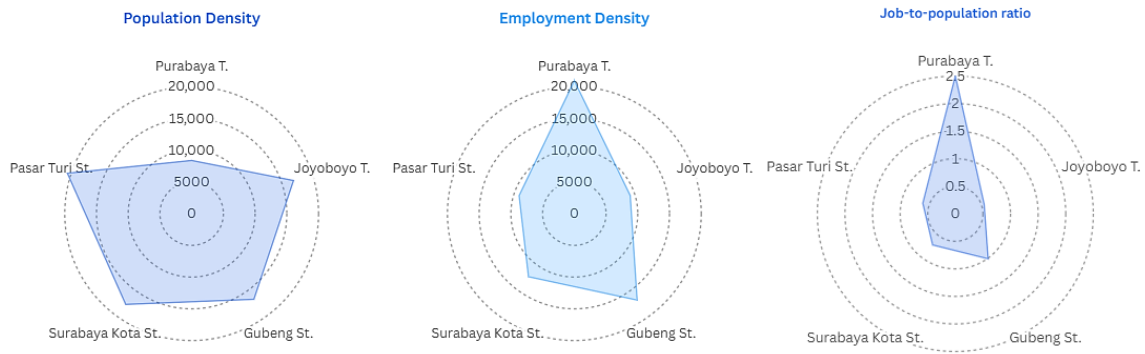
Surabaya Kota Station presents an increasing population density gradient peaking at 1,200 m (17,681 people/km<sup>2</sup>), suggesting the area surrounding the station is underutilized in residential terms. Nonetheless, it has one of the highest employment densities in the 800 m zone (15,905 jobs/km<sup>2</sup>) as seen in Figure 6, making it a significant employment hub. Its job-to-population ratio of 0.70 reflects a moderate balance, leaning slightly toward employment. This pattern indicates strong TOD potential, particularly if supported by residential intensification around the core. Purabaya

Terminal is characterized by an opposite pattern. Within the 400-meter buffer, it exhibits relatively low population density (7,479 to 8,382 people/km<sup>2</sup>), but the highest employment density at 400 m (209,355 jobs/km<sup>2</sup>). This condition arises because much of the core area is occupied by the terminal complex itself, which requires a large amount of land to accommodate its multiple platforms, bus bays, and parking areas. Unlike train stations, which generally occupy a more compact footprint, Purabaya is designed to serve a wider range of services: city buses, intercity buses, and even inter-regional/provincial routes. As a result, the land immediately surrounding the terminal is dominated by transport infrastructure rather than residential functions. This explains why population density increases only at greater distances (800–1,200 m), where residential areas begin to emerge. When cross-analyzed with BEI outcomes, this characteristic makes Purabaya more responsive to employment, or job-to-population-weighted scenarios rather than population-focused ones, reflecting its role as a regional transport gateway rather than a neighborhood-serving hub. Joyoboyo Terminal, in contrast, shows consistent but relatively modest performance in population and employment metrics. Population density remains steady across all radii (16,255 to 16,886 people/km<sup>2</sup>), while employment density is low (ranging from 4,286 to 9,262 jobs/km<sup>2</sup>). The job-to-population ratio 0.55 reflects a residentially dominated environment with few local jobs. This is because Joyoboyo does not require an extensive land footprint, as it serves fewer routes and primarily functions as a city bus terminal. This means the terminal complex occupies less land, leaving more surrounding space for residential development even at proximity to the hub. However, when analyzed against BEI outcomes, Joyoboyo's steady residential base is not matched by a strong diversity of land uses. Its lower scores in mixed-use and employment-focused scenarios suggest that despite stable densities, the area lacks the functional variety needed to fully support TOD-oriented growth.

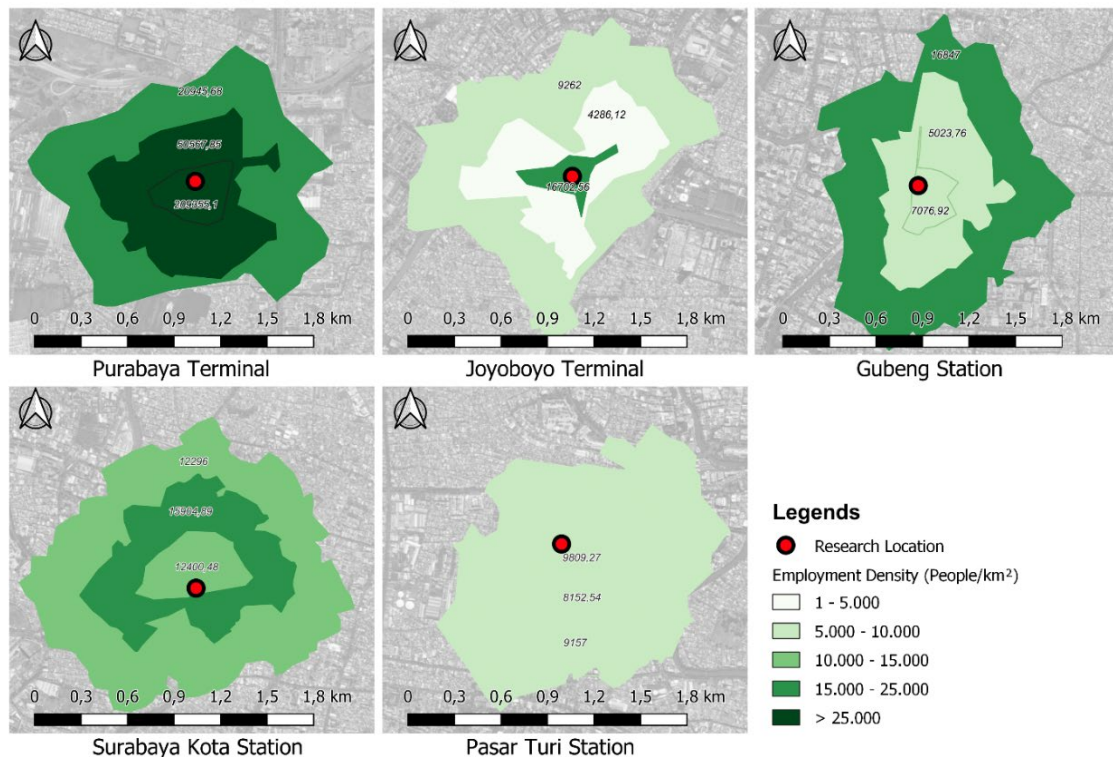


**Figure 4.** Population Density Distribution within the 400 m, 800 m, and 1,200 m Service Areas of Five Major Transit Hubs in Surabaya. The Darkest Zones Represent Areas with the Highest Residential Concentration

Among the transit hubs under consideration, Gubeng Station emerges as a frontrunner in embodying the tenets of TOD, distinguished by an apex population density and an exemplary job-to-population ratio [34]. This configuration not only underscores a robust residential concentration in the station's immediate vicinity but also indicates a self-sustaining ecosystem where employment opportunities closely match the residential base, diminishing the necessity for long-distance commuting [13]. The principles of TOD emphasize the creation of compact, mixed-use developments within walking distance of transit facilities, aiming to reduce reliance on motorized vehicles and promote pedestrian-friendly environments [4]. This equilibrium is crucial for fostering a walkable environment where residents can easily access jobs, services, and amenities without relying on private vehicles. The success of TOD hinges on carefully calibrating land use policies, transportation investments, and urban design strategies to create synergistic relationships between transit infrastructure and surrounding communities. Integrating land use and transportation planning is central to TOD, ensuring that residential, commercial, and recreational areas are well-connected and easily accessible by public transit [35]. Furthermore, light rail transit systems are integrated within the transit-oriented developments [36]. TOD implementations in other regions of the world have demonstrated the potential for these developments to create sustainable, livable communities that offer a viable alternative to car-dependent suburban sprawl.



**Figure 5.** The Population Density, Employment Density, and Job-to-Population Ratio in the Five Main Hubs within 1,200-Meter Boundaries



**Figure 6.** Employment Density within the 400 m, 800 m, and 1,200 m Service Areas of Surabaya's Five Major Transit Hubs. The Darkest Zones Represent Areas with the Highest Employment Concentration

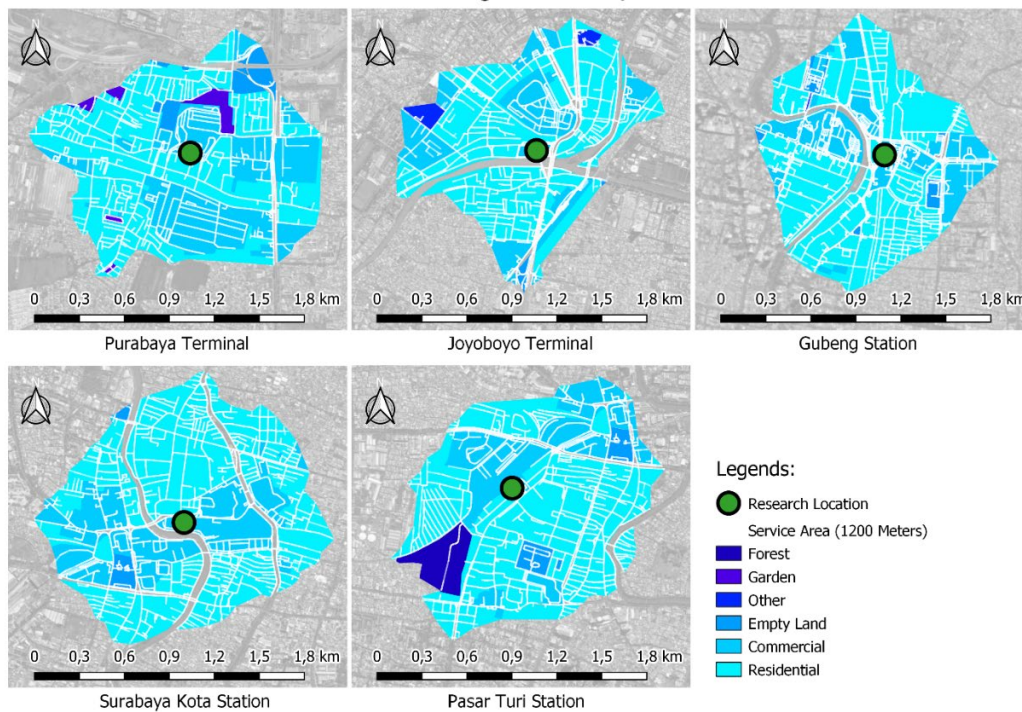
### Land Use Composition

The configuration of mixed-use land near transit hubs is another determinant of their potential for successful TOD [4]. Gubeng Station, identified as having a significant composition of mixed-use development, emerges as a promising candidate for TOD implementation due to the intrinsic relationship between land use diversity and enhanced accessibility [37].

Consistent with the principles of compact urban form and land use integration espoused by TOD theorists like Calthorpe and Bertolini, Gubeng Station exhibits a well-balanced mix of residential and commercial land uses within the 400-meter, 800-meter, and 1,200-meter catchments areas as illustrated in Figure 7 and Table 2, which fosters a walkable environment and reduces reliance on private vehicles [8,30]. This configuration directly supports the core characteristics of TOD, facilitating convenient access to daily needs and promoting the use of public transit [13].

In contrast, hubs such as Joyoboyo, Purabaya, and Pasar Turi demonstrate limitations in their land use diversity, presenting challenges to their TOD readiness and indicating a potential impediment to creating a vibrant, transit-supportive environment. Purabaya Terminal's diminishing mixed-use integration with increasing distance from the station, transitioning from a balanced mix at 400 meters to a predominantly residential composition at 1,200 meters, underscores the criticality of strategically planned land use patterns to sustain TOD objectives [35]. The principles

outlined in documents such as the Institute for Transportation Development and Policy Florida TOD Guidebook and Permen ATR No. 16 of 2017 emphasize the importance of a 400-800 meter radius for TOD areas, reachable within 5-10 minutes on foot, indicating that regions beyond this radius may not effectively contribute to TOD goals [34]. Achieving a synergistic relationship between land use and transit infrastructure is essential to cultivating sustainable urban environments, prioritizing accessibility, multimodality, and reduced automobile dependence. The success of TOD hinges on creating transit stations that are not only transportation nodes but also vibrant, mixed-use centers offering residents and commuters a wide array of amenities and services. Moreover, these stations must seamlessly integrate with the surrounding urban fabric, creating a cohesive and pedestrian-friendly environment that encourages transit ridership and reduces the need for private vehicles [38]. This balanced approach, characterized by integrating residential, commercial, and recreational spaces, is essential to fostering a sense of place and community while promoting economic activity and environmental sustainability. Examining Surabaya's transit hubs through the lens of TOD principles reveals valuable insights into the existing land use patterns and their impact on transit-supportive development.



**Figure 7.** Existing Land Use Distribution within the 1,200-meter Service Areas of Five Surabaya Transit Hubs. Light Blue Areas Represent Residential Zones, while Commercial Areas Appear in Darker Blue

**Table 2.** Land Use Ratio at the Five Hubs for Every Threshold

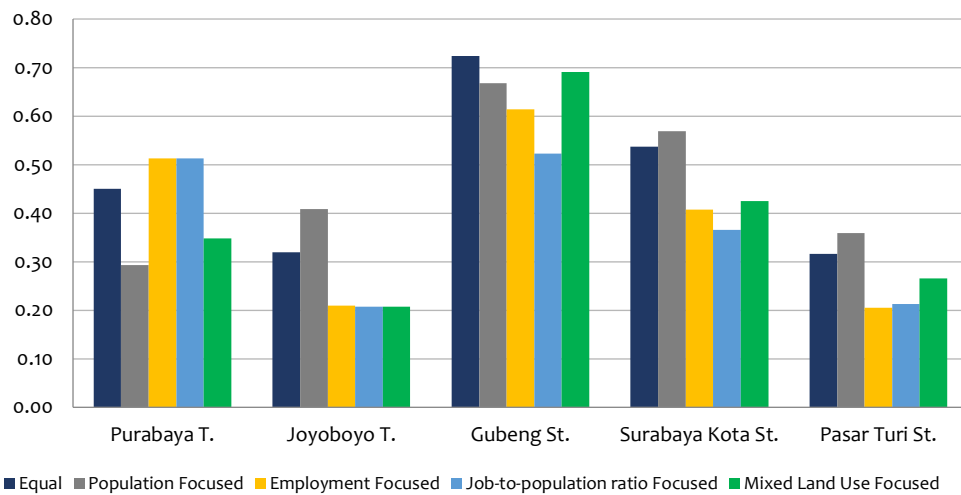
Hub	400 m Mixed-use (%)	800 m Mixed-use (%)	1,200 m Mixed-use (%)
Purabaya T.	R: 75.22 / C: 24.78 → 100%	R: 45.77 / C: 48.25 → 94.02%	R: 56.76 / C: 31.80 → 88.56%
Joyoboyo T.	R: 65.63 / C: 34.38 → 100%	R: 77.17 / C: 22.83 → 100%	R: 61.81 / C: 23.97 → 85.78%
Gubeng St.	R: 41.09 / C: 58.91 → 100%	R: 66.27 / C: 33.3 → 99.57%	R: 67.89 / C: 28.92 → 96.81%
Surabaya Kota St.	R: 47.40 / C: 52.60 → 100%	R: 50.06 / C: 48.23 → 98.29%	R: 63.08 / C: 26.49 → 89.57%
Pasar Turi St.	R: 89.84 / C: 10.16 → 100%	R: 68.35 / C: 23.26 → 91.61%	R: 65.19 / C: 23.64 → 88.83%

**BEI**

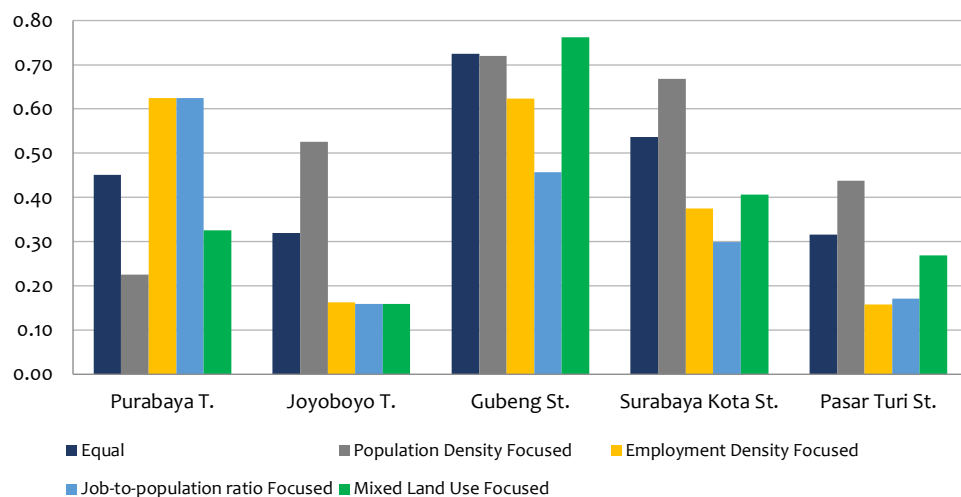
Gubeng Station consistently records the highest BEI scores across nearly all scenarios, with values approaching 0.6 to 0.7 (Figures 8 and 9). Its strongest performance is observed in the Mixed Land Use Focused, Equal Weight, and Population Density Focused scenarios. This combination of high mixed-use composition and concentrated population density creates an environment highly accessible by walking and biking, thereby strengthening the efficiency and effectiveness of transit operations. Surabaya Kota Station also demonstrates relatively high BEI values, with consistent performance across various weighting scenarios. It is particularly strong in the Population Density Focused scenario, where it reaches a score of approximately 0.62. These results reflect its location in a densely populated area with a moderately developed built environment, suggesting its readiness for further TOD-oriented improvements. Compared to Gubeng Station, Surabaya Kota Station is located near government offices, historic buildings, civic

facilities, and several logistic industries in the northern part of the city; these land uses occupy large blocks but accommodate few residents, which explains the relatively low density within 400 m compared to the higher residential densities found at 800–1,200 m.

Purabaya Terminal achieves high BEI scores under the Employment Density Focused and Job-to-Population Ratio Focused scenarios, with values ranging from 0.5 to 0.63. This pattern suggests a strong relationship between employment and residential densities in the area, although performance is less favorable under other scenarios. The terminal's strengths lie in its function as a major employment hub, though further enhancements in land use diversity and population density could strengthen its overall TOD suitability. Joyoboyo Terminal performs moderately in the Population Density Focused scenario but scores very low in the Mixed Land Use and Employment Density Focused scenarios. These results indicate limitations in land use diversity and the integration of work and residential functions. As a result, Joyoboyo may require significant intervention to enhance its suitability for TOD, particularly through diversification of functions and improvements in local employment opportunities. Pasar Turi Station ranks lowest overall in BEI scores, especially in the Mixed Land Use and Job-to-Population Ratio Focused scenarios, because the surrounding area lacks integrated development and functional diversity. Although its best performance occurs in the Population Density Focused scenario—with scores near 0.4—the station area remains predominantly residential, with weak employment support and limited potential for mixed-use development in its current form.



**Figure 8.** BEI Scores of Five Transit Hubs in Surabaya under 0.35 Target Weight Scenarios. Gubeng Station Consistently Ranks Highest across All Weighting Schemes, Indicating Superior TOD Readiness, while Joyoboyo and Pasar Turi Stations Score Lowest, Reflecting Limited Integration of Land Use and Density Indicators



**Figure 9.** BEI Scores of Five Transit Hubs in Surabaya under 0.5 Target Weight Scenarios

Gubeng Station maintains top performance across all focus areas, with especially high scores in Mixed Land Use and Equal weighting. Purabaya Terminal scores highest under Employment and Job-to-Population Ratio Focused scenarios, while Joyoboyo and Pasar Turi Stations continue to lag in most categories, highlighting their limited TOD-supportive characteristics.

The findings indicate that TOD readiness in Surabaya is most strongly influenced by land use mix, population density distribution, and the functional role of each hub. Among these, land use mix emerges as the most critical factor because it simultaneously condenses employment opportunities and residential presence, thereby fostering walkability and supporting transit efficiency. Population density near the core also plays a decisive role, as hubs with compact residential clustering such as Gubeng perform better than those with underutilized cores like Purabaya or Surabaya Kota. Finally, the scale and land occupation of transit infrastructure, particularly large bus terminals, affect TOD integration by limiting available space for housing or mixed functions. Local research highlights the significant role of paratransit and user perceptions in shaping service patterns around bus terminals, suggesting that terminal-type hubs require distinct planning measures compared to rail stations [39]. Together, these factors highlight that a balanced, well-integrated built environment is essential to strengthen TOD implementation in Surabaya.

In recapitulation, the Built Environment Index emerges as an indispensable analytical instrument for pinpointing and prioritizing Transit-Oriented Development prospects within the ambit of urban transit hubs [40]. Its significance lies in its capacity to furnish a nuanced comprehension of the intricate interplay between land use, transportation infrastructure, and urban morphology, thereby enabling stakeholders to make judicious decisions pertaining to urban planning and development [4]. The multi-scenario framework, inherent to the Built Environment Index, offers versatile insights into the intrinsic strengths and vulnerabilities of distinct locales, steering planners and policymakers toward the adoption of more strategic and context-sensitive developmental paradigms [30]. This approach resonates with the imperative for benchmarking indicator-based methodologies within urban areas, incorporating diverse local considerations to bolster the enduring sustainability of cities [41]. The index's capacity to accommodate multiple scenarios is particularly salient, as it permits stakeholders to evaluate the ramifications of diverse policy interventions and investment choices, thereby facilitating evidence-based decision-making. Moreover, the Built Environment Index aligns with the broader objective of fostering sustainable urban development, which necessitates a holistic synthesis that integrates environmental concerns with human well-being [42]. By furnishing a comprehensive assessment of the built environment, the index empowers decision-makers to prioritize investments that not only bolster economic growth but also enhance the quality of life for city denizens [43]. By analyzing the connectivity principle, which assesses green infrastructure, a trade-off between investment decisions can be set up that helps balance positive social, economic, and ecological effects throughout a city-region [44]. To allow social cohesion, mainly by providing travelers with services which may allow to organize the transport better, it is necessary to structure the transportation system according to sustainability requirements [45].

## CONCLUSIONS

This study examined population density, employment density, land use mix, and their integration through the BEI to evaluate the TOD readiness of five major transit hubs in Surabaya. The results consistently identify Gubeng Station as the most TOD-supportive hub, characterized by its high density and balanced land use composition, which together enable strong accessibility by walking and biking and reinforce transit efficiency. Surabaya Kota and Purabaya show moderate potential: the former is constrained by institutional and logistic land use near its core but benefits from rising residential intensity outward, while the latter functions more as a regional gateway with strong employment linkages but weak local residential integration. Joyoboyo and Pasar Turi display limited TOD alignment, with stable or high densities that are undermined by low land use diversity.

Beyond individual hub rankings, the findings provide broader insights into the determinants of TOD readiness. Land use mix emerged as the most decisive factor because it simultaneously condenses population and employment, creating the foundation for walkable, mixed-use environments that enhance transit ridership. Population density is also influential, but its effect is strongest when concentrated close to the hub rather than dispersed outward. Moreover, the type and footprint of transit infrastructure matters: compact train stations integrate more easily into their urban context, while expansive bus terminals may sacrifice TOD-supportive land use at their core.

For Surabaya, these results suggest clear planning priorities. Strengthening TOD should involve promoting land use diversification around hubs such as Pasar Turi and Joyoboyo, encouraging residential infill near Surabaya Kota, and leveraging Purabaya's role as a regional terminal by improving multimodal connections to surrounding neighborhoods. Policy frameworks that incentivize compact, mixed-use development will be crucial to transform transit hubs into activity centers that support sustainable mobility. Future research could refine these findings by incorporating additional dimensions of TOD, such as pedestrian network connectivity, housing affordability, or the role of informal land uses, to provide an even more comprehensive assessment of TOD readiness.

## REFERENCES

1. Chotib, and Rynjani, G.P.R., Travel Behavior towards Transit-Oriented Development in Dukuh Atas, DKI Jakarta, *Proceedings of the 2<sup>nd</sup> International Conference on Strategic and Global Studies (ICSGS 2018)*, 2019, doi: 10.2991/icsgs-18.2019.28.
2. Susetyarto, M.B., The Development Design Model for Bogor Station TOD Area, *IOP Conference Series Earth and Environmental Science*, 409(1), 2020, pp. 12037–12037, doi: 10.1088/1755-1315/409/1/012037.
3. Rosalin, A., Kombaitan, B., Zulkaidi, D., Dirgahayani, P., and Syabri, I., Towards Sustainable Transportation: Identification of Development Challenges of TOD Area in Jakarta Metropolitan Area Urban Railway Projects, *IOP Conference Series Earth and Environmental Science*, 328(1), 2019, pp. 12006–12006, doi: 10.1088/1755-1315/328/1/012006.
4. Putri, T.I. and Trisnawan, D., The Approach of Transit Oriented Development Principles in Indonesia, Case Study: Duren Kalibata, *AIP Conference Proceedings*, 2259, 2020, pp. 70027–70027, doi: 10.1063/5.0014731.
5. Helmmie, E. and Joewono, T.B., Elasticity of Travel Time and Travel Cost of Private Vehicles and Public Transportation in Bandung, Indonesia, *Civil Engineering Dimension*, 24(2), 2022, pp. 101–108, doi: 10.9744/ced.24.2.101-108.
6. Asriana, N. and Koerniawan, M.D., TOD Model through Low Carbon City Concept in Urban Design (Case Study: Palembang, Indonesia), *IOP Conference Series Earth and Environmental Science*, 532(1), 2020, pp. 12017–12017, doi: 10.1088/1755-1315/532/1/012017.
7. Nguyen, T.M.C., Kato, H., and Phan, L.B., Is Built Environment Associated with Travel Mode Choice in Developing Cities? Evidence from Hanoi, *Sustainability*, 12(14), 2020, pp. 5773–5773, doi: 10.3390/su12145773.
8. Wahyulina, B.L. and Ellisa, E., The Potential of Transit-Oriented Development (TOD) and Its Typology in Block-A Area, *Proceedings of the 3<sup>rd</sup> International Conference on Dwelling Form (IDWELL 2020)*, 2020, doi: 10.2991/assehr.k.201009.006.
9. Chen, J.H., Ha, N.T.T., Chou, C.C., Wang, J.P., and Wang, T.K., Transit-Oriented Development: Exploring Citizen Perceptions in a Booming City, Can Tho City, Vietnam, *Sustainability*, 13(3), 2021, pp. 1370–1370, doi: 10.3390/su13031370.
10. Freydidg, M. and César, H., *Design of Non-Motorized Mobility Plan for Warm Climate Cities Case: Hermosillo, Sonora, Mexico*, Master's Thesis, 2016, [Online]. Available: <http://ninive.uaslp.mx/jspui/bitstream/i/4672/1/MCA1MFH201601.pdf>
11. Cervero, R., Transit-Oriented Development (TOD) and Land Use, in *Encyclopedia of Sustainability Science and Technology*, R. A. Meyers, Ed. New York, NY: Springer New York, 2012, pp. 10923–10934. doi: 10.1007/978-1-4419-0851-3\_269.
12. Cho, S., Choi, K., and Yi, Y., Proactive and Sustainable Transport Investment Strategies to Balance the Variance of Land Use and House Prices: A Korean Case, *Sustainability*, 14(21), 2022, pp. 14191–14191, doi: 10.3390/su142114191.
13. Hadi, W., Chrisnawati, Y., and Ikhsan, H.N., Public Transportation Accessibility: Towards Sustainable Transit Oriented Development (Case Study: Depok Baru Station – Jakarta, Indonesia), *IOP Conference Series Earth and Environmental Science*, 202, 2018, pp. 12012–12012, doi: 10.1088/1755-1315/202/1/012012.
14. Dirgahayani, P. and Choerunnisa, D.N., Development of Methodology to Evaluate TOD Feasibility in Built-up Environment (Case Study: Jakarta and Bandung, Indonesia), *IOP Conference Series: Earth and Environmental Science*, 158, 2018, p. 012019, doi: 10.1088/1755-1315/158/1/012019.
15. Duan, M., Xu, L., Chen, Y., Zhao, Q., Zhang, Y., Cui, X., and Tian, S., Optimizing Urban Environments for Sustainable Development: Strategies and Practices to Enhance Mobility Among Older Adults, *Sustainability*, 17(8), 2025, p. 3531, doi: 10.3390/su17083531.
16. Purnomo, D.A., Yulianta, Y., Utomo, D.P., and Sucipto, S., The Selection of PPP Type Through Value for Money Analysis: A Case Study of Jakarta-Surabaya Railway Project, *CSID Journal of Infrastructure Development*, 3(1), 2020, pp. 75–75, doi: 10.32783/csid-jid.v3i1.117.
17. Ajayi, O.O., Umar, A., Ibrahim, I., Olugbenga, L.A., and Abiola, A.A., Mathematical Modelling of Truck Platoon Formation Based on a Dynamic String Stability, *Vokasi Unesa Bulletin of Engineering, Technology and Applied Science*, 2(2), 2025, pp. 112–126, doi: 10.26740/vubeta.v2i2.34941.
18. Parygin, D.S., Aleshkevich, A.A., Golubev, A.V., Smykovskaia, T.K., and Finogeev, A., Map Data-driven Assessment of Urban Areas Accessibility, *Journal of Physics Conference Series*, 1015, 2018, pp. 42048–42048, doi: 10.1088/1742-6596/1015/4/042048.
19. Larasati, K.D., Pamungkas, A., and Nurlaela, S., Building Permit Regulation in Surabaya: A Review towards a Risk Management Perspective, *International Journal of Engineering Research and Technology (IJERT)*, 8(7), 2019, pp. 770-774, doi: 10.17577/ijertv8is070286.

20. British Council for Offices, *Guide Specification*, London, 2019.
21. BOMA International, *Office Space Standards and Guidelines*, Washington DC, 2017.
22. Seoudy, M.H., Menshawy, A.E., and Adawy, A.E., *A Transit Map for Micro-Scale Urban Development in Alexandria*, Egypt, 2023, doi: doi.org/10.12688/f1000research.125816.2.
23. Zheng, J., Garrick, N., Atkinson-Palombo, C., McCahill, C., and Marshall, W.E., Guidelines on Developing Performance Metrics for Evaluating Transportation Sustainability, *Research in Transportation Business & Management*, 7, 2013, pp. 4–13, doi: 10.1016/j.rtbm.2013.02.001.
24. Troy, A.R., Bonnell, L.N., and Littenberg, B., Relationship between the Built Environment and Body Mass Index in a Rural Context: A Cross-Sectional Study from Vermont, *Cureus*, 2018, doi: 10.7759/cureus.3040.
25. Liu, D., Analytical Forecasting of Population Distribution over Years in a New Rail Transportation Corridor, *Journal of Urban Planning and Development*, 142(4), 2016, doi: doi.org/10.1061/(asce)up.1943-5444.0000343.
26. Rakhmatulloh, A.R. and Dewi, D.I.K., Mapping of Road Network, Land Use, and Pedestrian Ways in CBD of Semarang, *IOP Conference Series Earth and Environmental Science*, 313(1), 2019, pp. 12016–12016, doi: 10.1088/1755-1315/313/1/012016.
27. Rahardjo, B., Mochtar, I.B., and Widyastuti, H., Pengembangan Infrastruktur Jaringan Jalan Rel di Surabaya Metropolitan Area, *IPTEK Journal of Proceedings Series*, 3(5), 2017, doi: 10.12962/j23546026.y2017i5.3116.
28. Al-Masaeid, H.R., AL-Tal, R.S., and Mahmoud, M.A., Effects of Urban Characteristics on Traffic Accidents, *Civil Engineering Dimension*, 27(2), 2025, pp. 142–151, doi: 10.9744/ced.27.2.142-151.
29. Barrington-Leigh, C. and Millard-Ball, A., A Global Assessment of Street-Network Sprawl, *PLOS ONE*, 14(11), 2019, p. e0223078, doi: 10.1371/journal.pone.0223078.
30. Yap, J.B.H., Chua, C.Y., and Skitmore, M., Towards Sustainable Mobility with Transit-Oriented Development (TOD): Understanding Greater Kuala Lumpur, *Planning Practice and Research*, 36(3), 2021, pp. 314–336, doi: 10.1080/02697459.2021.1883249.
31. Liu, Q., Kang, Z., Zhang, H., Song, R., and Li, G., A Case Study on Annoyance Noise Caused by Metro Railway at a TOD Developed Depot, *Advances in Civil Engineering*, 2022(1), 2022, doi: 10.1155/2022/3173567.
32. Teuber, M. and Sudeck, G., Why Do Students Walk or Cycle for Transportation? Perceived Study Environment and Psychological Determinants as Predictors of Active Transportation by University Students, *International Journal of Environmental Research and Public Health*, 18(4), 2021, pp. 1390–1390, doi: 10.3390/ijerph18041390.
33. Chava, J. and Newman, P., Stakeholder Deliberation on Developing Affordable Housing Strategies: Towards Inclusive and Sustainable Transit-Oriented Developments, *Sustainability*, 8(10), 2016, pp. 1024–1024, doi: 10.3390/su8101024.
34. Sari, F.B., Study of the Transit Oriented Development (TOD) Area of Jaticempaka, Pondok Gede District, Bekasi City, *International Journal of Science Technology & Management*, 4(2), 2023, pp. 499–503, doi: 10.46729/ijstm.v4i2.795.
35. Ibrahim, N.I., Adji, B.M., and Karim, M.R., Preliminary Study on Parking Control System for Proposed Transit Oriented Development (TOD) Area: Implementation Potential in Petaling Jaya City Council (MBPJ), Malaysia, *Proceedings of the Eastern Asia Society for Transportation Studies*, 8, 2011, pp. 230–230, doi: 10.11175/eastpro.2011.0.230.0.
36. Al-Thani, S.M. and Furlan, R., An Integrated Design Strategy for the Urban Regeneration of West Bay, Business District of Doha (State of Qatar), *Designs*, 4(4), 2020, pp. 55–55, doi: 10.3390/designs4040055.
37. Reinman, S.L., Open Knowledge Repository, *Reference Reviews*, 29(5), 2015, pp. 21–22, doi: 10.1108/rr-05-2015-0113.
38. Krisantinus, Y., Siahaan, U., and Simatupang, S., Bus Terminal Planning with the TOD Approach for Jakarta, Case Study Kampung Rambutan Bus Terminal, in *IOP Conference Series Earth and Environmental Science*, 878(1), 2021, pp. 12019–12019. doi: 10.1088/1755-1315/878/1/012019.
39. Joewono, T.B. and Kubota, H., Exploring Public Perception of Paratransit Service Using Binomial Logistic Regression, *Civil Engineering Dimension*, 9(1), 2007, pp. 1-8.
40. Buenk, R., Grobbelaar, S., and Meyer, I., A Framework for the Sustainability Assessment of (Micro)transit Systems, *Sustainability*, 11(21), 2019, pp. 5929–5929, doi: 10.3390/su11215929.
41. Hiremath, R., Balachandra, P., Kumar, B., Bansode, S.S., and Murali, J., Indicator-based Urban Sustainability - A Review, *Energy Sustainable Development/Energy for Sustainable Development*, 17(6), 2013, pp. 555–563, doi: 10.1016/j.esd.2013.08.004.
42. Tang, H.T. and Lee, Y.M., The Making of Sustainable Urban Development: A Synthesis Framework, *Sustainability*, 8(5), 2016, pp. 492–492, doi: 10.3390/su8050492.
43. Leibowicz, B.D., Urban Land Use and Transportation Planning for Climate Change Mitigation: A Theoretical Framework, *European Journal of Operational Research*, 284(2), 2019, pp. 604–616, doi: 10.1016/j.ejor.2019.12.034.
44. Rusche, K., Reimer, M., and Stichmann, R., Mapping and Assessing Green Infrastructure Connectivity in European City Regions, *Sustainability*, 11(6), 2019, pp. 1819–1819, doi: 10.3390/su11061819.
45. Ngossaha, J.M., Ngouna, R.H., Archimède, B., and Nlong, J.M., Sustainability Assessment of a Transportation System under Uncertainty: An Integrated Multicriteria Approach, *IFAC-PapersOnLine*, 50(1), 2017, pp. 7481–7486, doi: 10.1016/j.ifacol.2017.08.1064.