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Transit-Oriented Development in Emerging Cities: A Case Study of Railway Station Areas in Bandung, Indonesia

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Abstract

Transit-Oriented Development (TOD) is an urban concept that reduces dependence on private vehicles and promotes sustainable mobility. As one of Indonesia's metropolitan cities with a railway serving Bandung and its surrounding areas, Bandung can potentially adopt the TOD concept to address transportation and spatial planning issues. Therefore, this study takes three urban railway station areas as research objects, conducts a detailed evaluation of the comprehensive benefits of land use around these stations, and provides relevant recommendations. This study classifies urban railway transportation stations based on land use functions and establishes a three-tier comprehensive benefit evaluation index system across four dimensions: land use, population and building density, public transportation, and design. The research findings indicate that the Cikudapateuh stations meet five (5) basic TOD criteria, such as adequate pedestrian lane, mixed-use development, operational public transport service, public transport integration, and building coverage ratio (BCR). These findings indicate that TOD-based development in Cikudapateuh should be prioritized over the other two stations because it better meets the TOD criteria. The policy implications of this study recommend the need for synergy between spatial planning, strengthening transit infrastructure, and stakeholder participation to optimize TOD implementation, thereby achieving sustainable mobility in the future.

1. INTRODUCTION

Bandung is one of the largest metropolitan cities in Indonesia, serving as a hub for economic, educational, and tourism activities for both the people of Bandung and those in the surrounding areas. This has led to high mobility among the population, resulting in increasingly severe traffic congestion in Bandung year after year. According to research by Harahap et al. (2022), there are 8,565 vehicles per hour on the busiest roads, while the capacity of these roads is only 5,675 vehicles per hour. This suggests that Bandung needs to explore alternative solutions to reduce urban mobility. Conventional approaches, such as restricting private cars, are deemed insufficiently effective as they only address the user side, while improvements to transportation services are also necessary. An integrated alternative solution to reduce mobility is Transit-Oriented Development (TOD), which has been successfully implemented in various cities worldwide to create compact, walkable areas connected to mass transportation (Calthorpe, 1993; Handayeni, 2012).

TOD is a development model that integrates land use and public transportation, with three main principles: density, diversity, and pedestrian-friendly design (Calthorpe, 1993). Since the introduction of this concept in the 1970s, transportation-oriented development (TOD) has experienced rapid growth in Asian cities, such as Hong Kong. Railway stations are built alongside residential-commercial tower clusters and government services to form a new lifestyle – a "railway village." This concept has proven effective in reducing traffic congestion and air pollution and promoting economic growth, as seen in the successful implementation of TOD in Surabaya, which increased public transportation usage (Isa & Handayeni, 2014). Extensive literature on the interaction between land use and transportation has demonstrated that various land use characteristics,

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including density, diversity, design, proximity to public transportation, and destination accessibility, synergistically influence travel behavior. TOD (Transit-Oriented Development) is an example of integrating these characteristics, encouraging a shift from reliance on private vehicles toward public transportation and non-motorized modes of transport (Choi & Guhathakurta, 2024).

Although it has potential, implementing TOD in Bandung presents some challenges. A study by Widyahari & Indradjati (2015) found that the main obstacles are a lack of coordination between stakeholders and unclear criteria for land readiness. Additionally, transportation policy in Bandung metropolitan area continues to focus on building new roads rather than integrating various modes of transportation (Widyahari & Indradjati, 2015). However, stations such as Kiaracondong, Cikudapateuh, and Bandung have high accessibility and are surrounded by commercial areas and residential neighborhoods, thereby meeting the basic principles of TOD. This study aims to identify the suitability of TOD principles in the Bandung Station Area, Kiaracondong Station, and Cikudapateuh Station based on land use, accessibility, and pedestrian infrastructure. Additionally, this study will provide policy recommendations to accelerate the implementation of TOD in Bandung.

2. LITERATURE REVIEW

Transit-Oriented Development (TOD) is an urban planning approach that aims to integrate mass transportation systems—particularly railways—with the development of surrounding areas in an integrated manner. This concept emerged in the 1970s as an innovative solution to address issues such as traffic congestion, inefficient land use, and environmental degradation resulting from reliance on private vehicles (Calthorpe, 2014; Cervero & Dai, 2014). According to Calthorpe (1993), TOD is a compact, transit-supportive, mixed-use development oriented toward pedestrians. The main principles of TOD, as formulated by Cervero & Kockelman (1997), are the "3Ds": Density, Diversity, and Design. These three factors are believed to reduce dependence on motor vehicles by improving accessibility through transit routes and facilitating sustainable mobility.

Furthermore, Cervero and Murakami (2009) expanded this principle into "5D," which includes: Density, Diversity, Design, Distance to transit, and Destination accessibility. Their research emphasizes that the success of TOD is not only influenced by physical factors but also by adequate distance and accessibility, thereby reducing travel time and increasing the area's attractiveness. Another study by Song & Knaap (2004) states that the success of TOD depends on strong integration between spatial planning, transportation, and economic development. Song & Knaap (2004) emphasize that fiscal policies and incentives are crucial in encouraging developers to build in TOD zones, especially in areas with primary access to train stations. There is also research on the optimal distance from a train station for development (Huang et al, 2021). Typically, a distance of approximately 400-800 meters from the station is ideal for pedestrians and public transportation users, equivalent to a walking time of about 5-10 minutes (Jiao et al, 2014; Calthorpe, 1993; Porter, 1997). In this area, development with a density and diversity of land use is most effective in increasing transit use and reducing the use of private vehicles.

Hong Kong is one example of the successful implementation of TOD in the form of "rail villages," which are areas that have developed around railway stations designed as centers of economic and social activity (Xue & Sun, 2018). Most stations in Hong Kong are surrounded by clusters of residential and commercial developments, indicating that the success of this development is supported by government policies that promote the integration of urban planning and transportation. In this study, Xue and Sun (2018) introduce the concept of development ratio to measure the efficiency of development around stations, reflecting the direct relationship between the level of development and the success of such development. The research findings suggest that dense and mixed-use development enhances accessibility, optimizes land use, and reduces the need for long-distance travel. In addition to Hong Kong, other countries such as Japan, South Korea, and Singapore have also extensively implemented the TOD concept. Studies by Kamruzzaman et al. (2014) in Brisbane, Australia, and Kikutake et al. (1960) on urban metabolism indicate that the success of TOD across

different cultures and contexts must adapt to local conditions, including walking culture, development regulations, and economic incentives.

The main benefits of TOD include increased use of public transportation, reduced traffic congestion, improved environmental sustainability, and increased property values around stations (Ewing & Cervero, 2010; Song & Knaap, 2004). Additionally, TOD can create a more pedestrian-friendly environment, improve quality of life, and strengthen the local economy. However, key challenges include regulatory constraints, high development costs, resistance from developers and residents, and the need for comprehensive long-term planning (Knaap et al., 2001). In Hong Kong, strict land use regulations and topographical conditions hinder large-scale development.

Table 1 Synthesis of Transit-Oriented Development (TOD) Literature

Variable	Renne	ITDP (2017)	LVPC (2011)	Regulation of the Minister of Land and Spatial Planning No. 16/ 2017	Synthesized Criteria
Land Use Diversity	- Multi-family homes - Office/retail dominant along main roads	- Mixed uses to reduce travel distance	NA	**Urban centre**: - 20–60% residential, 40–80% non-residential - ≥5 land uses (housing, commercial, office, culture, public facilities) - High/mid-rise housing - 10–15% open space (+20% public green **Sub-urban centre**: - 30–60% residential, 40–70% non-residential - ≥4 land uses - 10–15% open space (+20% public green space)	**Urban centre**: - ≥5 land uses; - 20–60% residential - 40-80% non-residential - 10–15% open space (+20% public green space) **Sub-urban centre**: - ≥4 land uses; 30–60% residential - Office: 30–70% - Public space: 5–15% - 10–15% open space (+20% public green space)
Density	- High density	- High-density housing/jobs near transit	**Housing**: - Urban centre: >20 people/ha - Sub urban: >35 people/ha **Jobs:** - >50 peopla/ha	**Population**: - Urban centre: >750/ha - Sub-urban centre: 450–1500/ha **Jobs**: - Urban centre: >200/ha - Sub-urban centre: 40–200/ha **Housing**: - Urban centre: 20–75 units/1000 m² - Sub-urban centre: 12–38 units/1000 m²	**Population:** >750 people/ha **Housing:** - Urban centre: 20–75 units/1000 m² - Sub-urban centre: 12–38 units/1000 m²
Design (Accessibility)	- Grid street patterns - Pedestrian-focused	- Safe bike/pedestrian networks - Walkable transit access	NA	- 400–800m radius (physical boundaries) - Grid streets - Sidewalks on all roads	- Bike lane - Adequate pedestrian lane
Intensity (Building Floor Area Ratio and Building Coverage Ratio)	- Compact development	NA	NA	**Urban centre**: - BFAR >5.0 - High-rise (11–40 floors) - BCR 80% max lot coverage **Sub-urban centre**: - BFAR 3.0–5.0 - Mid-rise (3–15 floors) - BCR 70% max lot coverage	**Urban centre**: - BFAR >5.0 - BCR 80% max lot coverage **Sub-urban centre**: - BFAR 3.0–5.0 - BCR 70% max lot coverage

Variable	Renne	ITDP (2017)	LVPC (2011)	Regulation of the Minister of Land and Spatial Planning No. 16/ 2017	Synthesized Criteria
Public transport service	NA	NA	- Headway <15 min - 17h/day service - Commuter train 20 times a day	**Urban centre**: - Headway <5 min - Multi-modal (BRT, minibuses, and rail) **Sub-urban centre**: - Headway 5–15 min - Multi-modal (BRT, minibuses, and rail)	- Headway ≤15 min - 17h/day service - Commuter train 20 times a day - There are public transportation routes

Theoretically, literature indicates that the success of TOD is greatly influenced by density regulations, land use diversity, pedestrian-friendly infrastructure design, and optimal distances from train stations. Successful implementation has proven capable of creating more sustainable urban environments and a better quality of life. In the future, the need for supportive policies, economic incentives, and community participation will be crucial in driving the widespread development of TOD.

3. METHODS

This study employs a mixed-methods approach, integrating quantitative descriptive analysis and qualitative comparative evaluation to assess the potential for Transit-Oriented Development (TOD) implementation at Kiaracondong Station, Bandung Station, and Cikudapateuh Station. The methodology is structured into three phases: (1) data collection, (2) multi-criteria analysis, and (3) comparative benchmarking against global TOD standards. This approach ensures a comprehensive evaluation of land-use diversity, transport accessibility, and urban density, aligning with established TOD frameworks (Cervero & Kockelman, 1997; ITDP, 2017).

Primary and secondary data were collected to ensure analytical rigor. Secondary data included regulatory reviews of Indonesia's TOD guidelines, the Minister of Land and Spatial Planning Regulation No. 16/2017, and global best practices from the Institute for Transportation and Development Policy (Ministry of Land and Spatial Planning, 2017; ITDP, 2017). Geospatial and demographic datasets were sourced from government agencies. The primary data consisted of field surveys conducted at selected transit nodes, measuring pedestrian infrastructure, public transport service quality, and land-use mix.

Next, a qualitative approach is employed, utilizing a comparative analysis method. This method aims to identify gaps between actual conditions and TOD principles through systematic comparison (Nazir, 2005). Variables like land use, parking availability, and transportation mode integration were compared with global TOD criteria. The quantitative approach is used to assign a score to each variable. A score of 1 is assigned to variables that meet TOD principles, and a score of 0 is assigned to those variables that do not meet the principles. The scores will be calculated as the percentage of compliance for each variable (Giffary et al., 2022). The results are visualized in a suitability matrix to determine the area's readiness level.

The Land Use Mix Index is also calculated in this study by comparing the area of residential and non-residential land (Burton, 2000). To analyze land use mix, it is essential to define a spatial radius to accurately interpret the TOD area. In this study, the spatial radius is 600 metres, which was clipped by the ArcGIS software (Calthorpe, 1993). An index value close to 1 indicates an ideal balance for TOD, while a value greater than 1 indicates a dominance of residential areas that require functional diversification intervention. The following formula is used to calculate the land use mix index.

$$\textbf{\textit{Land use mix index}} = \frac{(\textbf{\textit{Residential land area}})}{\textbf{\textit{District area}} - \textbf{\textit{Residential land area}}}$$

Next, density analysis was measured using a composite index that combines population density, settlement density, and built-up land density. Areas with index values above the 75th percentile are considered to meet

TOD density requirements, while values below the 25th percentile require density increase policies. Measuring the intensity of building utilization is also conducted in this study, where building intensity is the allocation and distribution of the maximum floor area of a building relative to its designated land/site to achieve good efficiency and effectiveness of utilization. Building utilization intensity consists of the Building Floor Area Ratio (BFAR) and Building Coverage Ratio (BCR), calculated using the following formula (Regulation of the Minister of Public Works No. 06/2007).

$$\boldsymbol{BFAR = Number\ of\ Floors \times Land\ area}$$

$$\boldsymbol{BCR = \frac{Building\ area}{Land\ area} \times 100\%}$$

Finally, public transportation services can be analyzed based on the modes of public transportation that serve the station area and their frequency of service. The modes of public transportation that serve the station are intended to determine whether the train station is integrated with other modes of public transportation, such as Minibuses and BRT. Minibuses and BRT are also evaluated based on the daily number of vehicles per route operating in the planned area. In addition to minibuses and BRT, the frequency of commuter trains served at each station is also assessed, including headway, type of train service, number of train units, and daily train operations.

4. RESULTS

This section will present the analysis results based on the previously determined methods. The results section comprises six subsections: mixed land use, density analysis, public transport services, design (accessibility), building intensity analysis, and a comparative analysis of the three stations.

4.1 Land use diversity

A land use diversity analysis was conducted using the buffer method in ArcGIS software to determine the radius of the area. Based on Regulation of the Minister of Land and Spatial Planning No. 16/2017, the radius was determined to be 600 meters from the transit point. Other provisions state that an area that can be developed into a TOD must have at least five land use types, consisting of 20-60% residential and 40-80% non-residential, including 30-70% office centers and 5-15% open spaces. The Land Use Mix Index calculation was also used in the analysis to assess the potential for TOD development.

Based on the analysis results, it was found that the three study areas—Bandung Station, Cikadapateuh Station, and Kiaracondong Station Area—have more than five land use types. The Bandung Station Area comprises 72.3% residential, 26.9% non-residential, 19.4% office center, and 0.8% open space. The land use mix index for the Bandung Station Area shows a value of 2.62. This means that, based on land use composition and land use mix index criteria, the Bandung Station Area does not yet meet the requirements for a TOD area.

The Cikudapateuh Station area comprises 72.5% residential, 20.7% non-residential, 12% office and commercial center, and 6.9% open space. Additionally, the mixed land use index calculation yields a value of 2.63. The Kiaracondong Station Area comprises 80.9% residential, 13.2% non-residential, 3% office and commercial center, and 5.9% open space. The land use mix index for this area reaches 4.24. Based on the analysis of land use diversity and the land use mix index, it can be concluded that the Cikudapateuh Station Area and Kiaracondong Station Area do not yet meet the criteria for TOD potential. Figure 1 below provides an overview of land use composition at the three study areas.

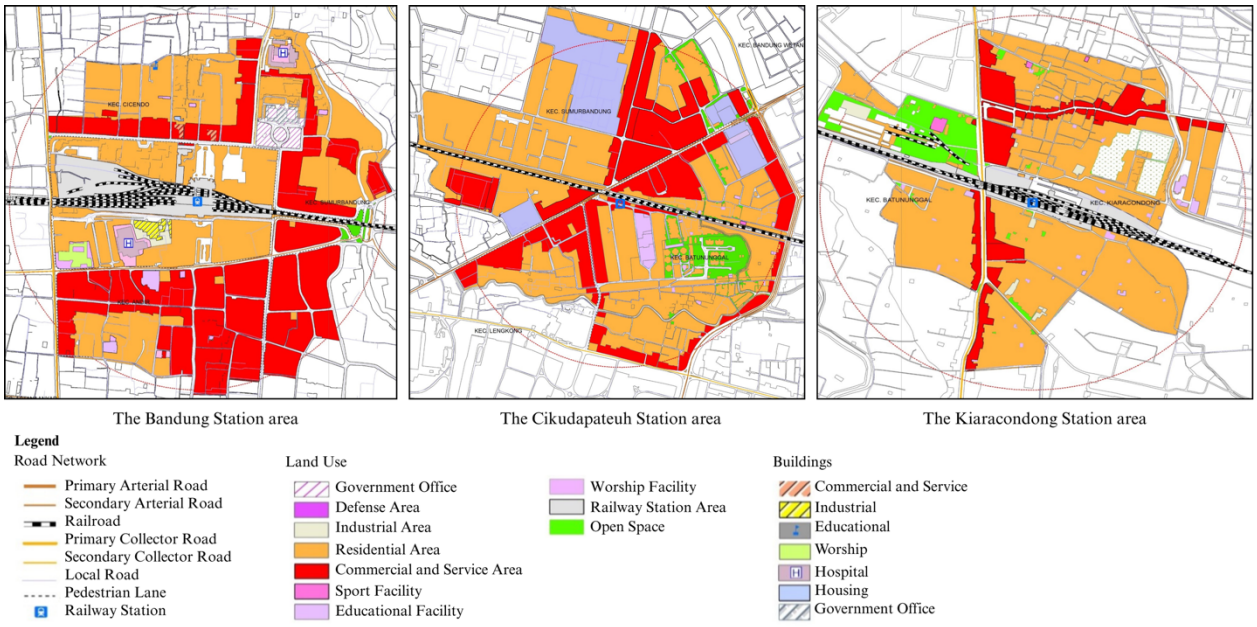

Figure 1. Map of landuse in the study areas

4.2 Density

Density analysis consists of population density and building density. To support the criteria for implementing TOD, an area was determined to have a high population and building density. Based on Regulation of the Minister of Land and Spatial Planning No. 16/2017, to fulfill the TOD criteria, the population density must be greater than 750 people/ha, and the housing density must be between 20 and 75 units/1000 square meters.

According to the analysis results, the Bandung Station area has a population density of 175 people/ha and a housing density of 4 units/1000 m2. The Cikudapateuh Station area has a population density of 320 people/ha and a housing density of 8 units/1000 m2. The Kiaracondong Station area has a population density of 420 people/ha and a housing density of 6 units per 1,000 square meters. This indicates that none of the three study areas meet the criteria for a TOD zone. Population and housing density remain low compared to the established criteria.

4.3 Design (Accessibility)

Accessibility analysis in TOD consists of bike lanes and pedestrian lanes. These elements facilitate convenience in reaching destinations by offering various alternative routes to the destination location. This study includes observations regarding the condition of the bike lane and the pedestrian lane at each study area.

The Bandung Station area is dominated by residential, commercial, and service areas, drawing significant pedestrian traffic. To facilitate pedestrian movement, the pedestrian lane features a width ranging from 2.5 to 4 meters. This width is generally considered suitable for pedestrian use; however, the condition is inadequate due to street parking and extensive tree roots protruding onto the path. Consequently, pedestrians often experience discomfort and walk on the roadway. Furthermore, the area lacks a designated bike lane, forcing cyclists to use the same space as motorized vehicles.

Figure 2. Pedestrian Lane on Bandung Station Area

The Cikudapateuh Station area has various land uses which dominated by residential and commercial and service area. The features of pedestrian lane exceeds 2 meters. Generally pedestrian lane in this area adequately provided along the main thoroughfare, Jl. Ahmad Yani, yet neighborhood areas in the vicinity lack sufficient pedestrian lane. These areas are narrower, measuring less than 2 meters, and are often obstructed by tree roots. The comfortable pedestrian lane primaly is only to Ahmad Yani Street and Malabar Street. Furthermore, the Cikudapateuh Station area lacks designated bike lane, forcing cyclists to use the same space as motorized vehicles.

Figure 3. Pedestrian Lane on Cikudapateuh Station Area

The Kiaracondong Station is dominate by residential and commercial and service are. The average width of pedestrian lane exceeds 2 meters. However, their condition is compromise by the presence of street vendors. The existence of Kiaracondong market significantly contributes to the deterioration of the traffic, as many traders operate outside the market. The pedestrian lane is available along Ibrahim Adjie Street, which are often in poor condition, obstructed by waste and big trees. Furthermore, the Kiaracondong Station area lacks designated bike lane, forcing cyclists to use the same space as motorized vehicles.

Figure 4. Pedestrian Lane on Kiaracondong Station Area

4.4 Intensity

The analysis of space intensity in this study includes the existing building floor area ratio (BFAR) and building coverage ratio (BCR) values. This analysis is used to compare the existing ratios with the ratios specified in Regulation of the Minister of Land and Spatial Planning No. 16/ 2017. The BFAR criteria that must be met for the central city area are >5.0 and 3.0-5.0 for the suburban center. Meanwhile, the BCR criteria are 80% for the central city area and 70% for the suburban center.

Based on the results of the analysis, it was found that the Bandung Station Area has an average BFAR of 1.70 and a BCR of 47% of the required 80%. This means the BFAR criteria are not yet met as a TOD potential because no buildings with a mixed-use concept exist in this area. The buildings have their respective functions and are not integrated. However, the BCR value still meets the criteria for land coverage. The Cikudapateuh Station Area has an average BFAR of 1.39 and a BCR of 57% of the required 70%. The Kiaracondong Station area has an average BFAR of 0.91 and a BCR of 52% of the required 70%. Both areas show low BFAR values, thus failing to meet the criteria for TOD potential. This is due to the absence of buildings with a mixed-use concept in these areas. Meanwhile, the BCR value still meets the requirements as it is below the maximum value.

4.5 Public transport service

Based on Appendix II of Regulation of the Minister of Land and Spatial Planning No. 16/2017, it is explained that a key prerequisite for the development of TOD areas is the development of a public transportation system, as it can create a market as an attraction for activities around transit hubs. The success of TOD is influenced by the number of public transport users at transit hubs. It indicates that the presence of stations is a urgently for supporting TOD areas. Public transportation analysis refers to the modes of public transportation operating around the station, as well as their service frequency. The modes of public transportation referred to in this study are intended to examine the integration of other modes with the train station, including minibuses and buses. The indicators examined for these public transportation modes include the number of vehicles per route passing through the study area each day. Additionally, the frequency of commuter trains served at each station is analyzed, including headway ≤15 minutes, type of train service, 20 times a day for commuter trains, and train operations for 17 h/day service.

Public transportation services around Bandung Station are known to include 17 (seventeen) minibus routes and 2 (two) bus (BRT) routes that pass through the area. In this regard, Bandung Station is well-integrated with other public transportation modes, providing convenient accessibility for train passengers to the surrounding areas without the need for private vehicles. The high number of routes results in many vehicles passing through the area, reaching up to 130 units per day. In serving commuter trains, Bandung Station operates for 20 hours, serving three main destinations: the Bandung Raya Local Train to Cicalengka, which has 18 train sets with a headway of 55 minutes; the commuter train to Padalarang, which has 19 train sets with

a headway of 1 hour; and the Bandung Raya Train to Cibatu and Purwakarta, each of which has only one train set and operates at one time only.

Next, public transportation services around Kiaracondong Station have only 8 (eight) minibus routes. In serving commuter trains, this station serves local and commuter trains for three main destinations. The services that operate consist of the Bandung Raya Local Train, which has routes from Padalarang to Purwakarta and Cicalengka to Cibatu; the Cibatu/Simandra Local Train, with destinations to Purwakarta and Cibatu; and the Galunggung Train, which has a destination to Tasikmalaya. Each destination has different operating hours: 20 hours for the Bandung Raya Local Train to Cicalengka, Padalarang, and Cibatu, while the local train to Cibatu only operates for 2 hours. 8 (eight) minibus routes serve access to the area around Kiaracondong Station, and no bus routes pass through this area. This is due to the narrow roads around the market leading to Kiaracondong Station, which is caused by the expansion of street vendors onto the roadways.

Finally, Cikudapateuh Station is smaller than Bandung and Kiaracondong Stations. Public transportation services around this area include 3 (three) minibus routes and 3 (three) bus routes. This station serves only the commuter trains, AC Patas KRD, and Bandung Raya Patas KRD routes to Cibatu and Bandung Raya. This station operates for 17 hours, serving passengers for routes to Padalarang, Cicalengka, Purwakarta, and Cibatu. Looking at the public transportation routes passing through the station, there are 3 (three) minibus routes and 3 (three) bus routes. Despite having limited routes, the station's location is strategically positioned to access shopping centers such as the Kosambi market.

4.6 Comparison of three stations

A comparative analysis was conducted to compare the characteristics of the three study areas and determine which one has the potential to apply the TOD concept. Based on the analysis results, it can be concluded that the three study areas have potential for implementing the TOD concept. The Cikudapateuh Station Area has greater potential as its existing conditions are suitable for the criteria of TOD as it has higher scoring than other areas namely 35%. This analysis indicates that each station shares similar characteristics. However, their respective analyses yield differing suitability values. The following are the results of the comparison:

Table 2. Results of the comparative analysis of TOD criteria at three stations

No	Variable	Criteria	Results			Score		
			A	B	C	A	B	C
1	Land Use Diversity	**Urban centre**: - ≥5 land uses; - 20–60% residential - 40-80% non-residential - 10–15% open space (+20% public green space)	≥5 land uses 72.3% residential 26.9% non residential 0.8% open space	≥5 land uses 72.5% residential 20.7% non residential 6.9% open space	≥5 land uses 80.9% residential 13.2% non residential 5.9% open space	1 0 0 0	1 0 0 0	1 0 0 0
2	Density	**Population:** >750 people/ha **Housing:** 20–75 units/1000 m²	175 people/ha 4 units/ 1000 m²	320 people/ha 8 units/ 1000 m²	420 people/ha 6 units/ 1000 m²	0 0	0 0	0 0
3	Design (Accessibility)	- Bike lane - Adequate pedestrian lane	- No bike lane - Inadequate pedestrian lane	- No bike lane - Adequate pedestrian lane	- No bike lane - Inadequate pedestrian lane	0 0	0 1	0 0
4	Intensity (Building Floor Area Ratio and Building Coverage Ratio)	**Urban centre**: - BFAR >5.0 - BCR 80% max lot coverage	BFAR 1.70 BCR 47%	BFAR 1.39 BCR 57%	BFAR 0.91 BCR 52%	0 1	0 1	0 1

No	Variable	Criteria	Results			Score		
			A	B	C	A	B	C
5	Public Transport Service	- Headway ≤15 min - 17h/day service - Commuter train 20 times a day - There are public transportation routes	- Headway 55 min - 20h/day service - Commuter train 18 times a day - 17 routes of minibus and 2 routes bus (BRT)	- Headway 60 min - 17h/day service - Commuter train 18 times a day - 3 routes of minibus and 3 routes bus (BRT)	- Headway 58 min - 20h/day service - Commuter train 17 times a day - 8 routes of minibus (BRT) (√)	0 1 0 1	0 1 0 1	0 1 0 1
					Total	29%	35%	29%

A= Bandung Station
B= Cikudapateuh Station
C= Kiaracondong Station

Scoring:
(1) fulfills Transit Oriented Development TOD criteria
(0) does not fulfill Transit Oriented Development TOD criteria

5. DISCUSSION

This study identifies the application of the Transit-Oriented Development (TOD) concept in Bandung, focusing on three railway stations: Bandung Station, Cikudapateuh Station, and Kiaracondong Station. The analysis results indicate that all three stations share similar aspects that meet the TOD criteria, with Bandung Station and Kiaracondong Station meeting 4 out of 14 TOD criteria, and the other station meeting 5 out of 14 criteria. This indicates that Cikudapateuh Station is the most suitable for implementing the TOD concept. At the same time, the other stations also have potential but still need to meet many of the main criteria. This finding addresses the recommendations from the research by Widyahari & Indradjati (2015), which stated that these three stations are potential and require further study. However, the results of this study differed, as implementing TOD at the three stations still requires meeting approximately 9–10 TOD criteria.

A key finding of this study is the imbalance in land use proportions at the three stations, where residential areas account for more than 70% of the area. This contradicts the TOD principle, which emphasizes a balance between residential (20-60%) and non-residential (40-80%) areas (Ministry of Land and Spatial Planning, 2017). A similar condition was also found in Isa & Hadayeni (2014) study in Surabaya, where the dominance of residential areas hindered the development of TOD areas by reducing space for commercial and public activities. At Bandung Station, for example, the low proportion of open space (0.8%) and office centers (19.4%) became the main obstacles, necessitating policy interventions to regulate a more balanced land allocation. This means that at all three stations, only the criteria for five types of land use were filled, while the portion of land use wasn't filled. This situation may be caused by minimal control over land use and the lack of incentive mechanisms for developing mixed-use buildings in the station area.

Although Isa & Hadayeni's (2014) research revealed that the implementation of TOD in Surabaya was quite successful, the criteria for land use proportion were not met, which explains that residential land dominates TOD areas. In line with our findings, the failure to meet the land use proportion criteria in all three TOD areas indicates that the dominance of residential functions in Transit-Oriented Development (TOD) areas is a common phenomenon in Indonesia. This finding challenges the assumption of the universality of Cervero's (1998) TOD model by showing that density does not automatically create diversity without strong policy intervention. Therefore, measures such as form-based zoning, progressive tax incentives, and land value capture mechanisms are needed to achieve sustainable and balanced TOD. Moreover, the Detailed Spatial Planning and Zoning Regulations of Bandung City for the period 2015-2035 stipulates that the three designated study areas are classified as high-density residential zones. This further indicates that the high density of residential areas occurs systematically, but on the other hand it can hinder the implementation of the TOD concept.

Bandung Station has the best public transportation integration with 17 minibus routes and two bus routes, while Kiaracondong Station is only served by minibuses. However, the frequency of train services in all three areas is currently low (headway of 1 hour), which does not meet the TOD standard (<15 minutes). These findings are consistent with Isa's (2014) research, which highlights the need to improve the frequency and quality of public transportation services to support TOD. Additionally, the lack of pedestrian facilities and bike lanes in all three areas hinders the creation of a walkable and bikeable environment, as explained in Renne's (2009) study.

Density analysis reveals that Kiaracondong Station has the highest population density (420 people/ha), yet it remains below the TOD standard for urban centers (exceeding 750 people/ha). Meanwhile, Bandung Station only reaches 175 people/ha, which is far from the ideal criteria. This low density is related to the dominance of inefficient horizontal settlements. In addition, building density is also very low in all three locations, with Bandung station having 4 units/1000 m², Cikudapateh 8 units/1000 m², and Kiaracondong station 6 units/1000 m². Research by Pushkarev and Zupan (1977) suggests that to support sustainable transportation, a high building density is necessary for an area, making vertical housing development and increased building intensity recommended solutions.

Aspects of area design, such as the availability of sidewalks and bicycle lanes, were also highlighted in this study. Although the sidewalks at all three stations met the minimum width standard (2 meters), many were in poor physical condition due to street activities and illegal parking. This reduced the comfort of pedestrians and people with disabilities, who should be a priority in TOD development (ITDP, 2017). A study by Handayeni (2012) also found that the inconvenience of pedestrian facilities is the main obstacle to implementing TOD. Therefore, improving sidewalks and adding bike lanes should be a focus in development plans.

Based on the analysis, the study findings reveal conflicts between theory and actual conditions, such as pedestrian lanes that are physically adequate but uncomfortable due to conflicts with informal activities (Cervero & Kockelman, 1997), or the availability of diverse modes of transportation with low frequency, rendering them ineffective (ITDP, 2017). This paradox suggests that physical indicators in TOD planning are insufficient on their own and must be examined holistically within the socio-economic context of the area. For example, the presence of poorly maintained pedestrian facilities reflects weak spatial management coordination, while low public transport frequency is linked to institutional fragmentation (Ray et al., 2020). This reflection highlights that the success of TOD depends not only on design but also on the integration of policies that are responsive to societal dynamics.

This study makes both theoretical and empirical contributions to the field of Transit-Oriented Development (TOD) in an emerging city. Theoretically, it refines the understanding of TOD principles within the Indonesian context by highlighting the common phenomenon of residential dominance in TOD areas and challenging the universal applicability of existing TOD models. This calls for a more nuanced approach that considers local conditions and strong policy interventions to achieve balanced land use. Empirically, the study provides a comparative assessment of three railway station areas in Bandung, identifying Cikudapateuh Station as the most suitable for TOD implementation. It identifies specific areas for improvement at all three stations, including increasing the frequency of train services, developing mixed-use vertical housing, and enhancing pedestrian facilities. These findings offer practical insights for policymakers and urban planners in Bandung and other similar cities seeking to implement TOD strategies. The research highlights the importance of collaboration among the government, the private sector, and the community in achieving sustainable and inclusive urban development.

Overall, this study confirms previous findings that the implementation of TOD depends on the availability of transportation infrastructure and the balance of land use, density, and pedestrian-oriented area design. Recommendations for TOD development in Bandung include: (1) increasing the frequency of train services, (2) developing mixed-use vertical housing, (3) improving pedestrian facilities & bike lanes, and (4) balancing land allocation for residential and non-residential areas. Implementing these policies requires collaboration

between the government, private sector, and community, as explained in Widyahari & Indradjati (2015) study on TOD development in the Greater Bandung Metropolitan Area.

6. CONCLUSIONS

This study identifies that the concept of Transit-Oriented Development (TOD) can be applied in Bandung, particularly in the Cikudapateuh Station area, as it meets several key criteria, such as land use diversity, building coverage ratio (BCR), adequate pedestrian lanes, and public transportation integration. However, the high dominance of residential land use and the imbalance between residential areas and non-residential facilities indicate the need for a more holistic approach in TOD planning. TOD theory emphasizes the balance of residential, commercial, and public spaces to create sustainable areas that are integrated with mass transportation. The results of this study confirm the hypothesis that the success of TOD depends not only on the availability of transit modes but also on comprehensive spatial planning, including density regulations, mixed-use development, and accessibility for pedestrians and bikes.

Based on the study's findings, the Bandung City Government needs to develop policies that encourage the implementation of TOD through revisions to zoning regulations to ensure a balanced land use ratio, particularly by increasing the proportion of commercial and public spaces around stations. Additionally, collaboration is needed among relevant agencies, such as the Transportation Department and the Spatial Planning Department, to enhance public transportation integration and provide adequate pedestrian infrastructure and bicycle lanes. Incentive policies for developers to build vertical housing and mixed-use buildings can also be a solution to optimize land use. These steps will support the creation of TOD areas that reduce dependence on private vehicles and improve the community's quality of life through a sustainable and inclusive environment. Additionally, we recommend implementing vertical residential areas in the TOD 3 station area to balance the proportion of each land use, considering that residential areas are currently the dominant land use. This approach can improve spatial efficiency while supporting the principles of TOD.

The limitations of this study lie in its scope, which focuses only on existing railway stations in Bandung City, without considering other transit points such as bus terminals or city transport stops, and does not include future public transport development plans such as LRT. Additionally, this study has not examined population density based on occupation type, which could provide a more in-depth understanding of transportation needs. Furthermore, the study has not explained the quality of physical indicators, such as criteria for pedestrian accessibility from both social and economic perspectives. For future research, it is recommended to expand the scope of the analysis to include various types of transit points, integrate plans for new transportation modes, and conduct a more detailed classification of population density based on economic activities, and delve deeper into the social and economic aspects of each physical indicator to enhance the accuracy and relevance of the research findings.

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