Identifying the Potential of Transit-Oriented Development in Surakarta City

Alif Asa Aryaputra, Anita Ratnasari Rakhmatulloh

Department of Urban and Regional Planning, Diponegoro University, Semarang, INDONESIA

E-mail: alifaryaputra@students.undip.ac.id

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ABSTRACT

Transit Oriented Development (TOD) is an urban development apporach that integrates land use and public transport to promote compact, accessible, and sustainable cities. In Indonesia, TOD has been widely discussed in metropolitan areas such as Jakarta and Bandung, but its implementation in medium-sized cities remains underexplored. Surakarta, a secondary city in Central Java, has incorporated TOD principles into its Spatial Plan (RTRW 2021-2041), positioning the Batik Solo Trans (BST) corridor as the backbone of urban mobility. However, the potential transit nodes that can serve as foundation for TOD development have not been systematically identified. This study aims to identify potential TOD nodes in Surakarta City based on spatial analysis of the BST corridor. Using Geographic Information System (GIS) methods, the research applies an 800-meter buffer analysis around transit stops to delineate TOD catchment areas, followed by overlay with land-use data, transportation networks, and strategic urban function. The analysis focuses on ten primary nodes along the BST corridor that represent both central and peri-urban contexts. The results reveal that central nodes such as Solo Balapan and Purwosari have the highest potential due to their strategic location, multimodal integration, and proximity to urban activity centers. In contrast, peri-urban nodes such as Kartasura and Palur exhibit weaker connectivity but provide opportunities for future expansion. This study contributes an initial spatial framework for assessing TOD readiness in medium-sized Indonesian cities, offering empirical evidence to support future TOD oriented planning and policy in Surakarta.

Keywords: Transit Oriented Development, transit nodes, spatial analysis, BST Corridor, urban planning.

INTRODUCTION

Urbanization and rapid motorization have increasingly become critical challenges for medium-sized Indonesian cities, including Surakarta. Rising dependence on private vehicle has contributed to congestion, air pollution, and inefficient land use [1], [2]. Addressing these challenges requires sustainable urban mobility strategies that integrate transport and spatial planning. One of the widely recognized approaches is Transit Oriented Development (TOD), which promotes compact, mixed-use, and walkable urban areas around transit nodes [3,4]. The concept was first articulated through the "3Ds" framework that contains Density, Diversity, and Design [3], and later expanded into broader dimensions including Destination Accessibility and Redevelopment [5]. TOD has been proven to support sustainable transportation, reduce greenhouse gas emissions, and foster urban competitiveness [6].

In Indonesia, TOD development has gained prominence in national and local policy agendas, particularly in metropolitan areas such as Jakarta and Bandung [7,8]. Studies in these cities have highlighted the potential of TOD to enhance accessibility and promote integrated urban growth. However, the application of TOD in medium-sized cities remains limited and underexplored.

Surakarta, as a medium-sized city in Indonesia, currently faces increasing challenges related to urban growth, land-use conversion, and rising dependence on private vehicles. These conditions contribute to congestion and inefficiencies in urban mobility, particularly along major corridors. To address these issues, the city has introduced the Batik Solo Trans (BST) as a bus rapid transit system that serves as the backbone of public transportation. The existence of the BST corridor provides a

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strategic opportunity to implement *Transit Oriented Development* (TOD), which integrates land use and transit to promote sustainable urban growth.

Identifying potential TOD nodes along the BST corridor is therefore crucial for directing future development and enhancing accessibility. Moreover, applying spatial analysis through Geographic Information Systems (GIS) offers significant advantages, as it allows the integration of land-use data, transport networks, and service facilities within a defined catchment area. This approach provides a systematic and evidence-based framework for evaluating TOD readiness and prioritizing interventions in Surakarta

Previous studies on TOD in Indonesia often focus on evaluating specific variables such as density, land-use diversity, or accessibility [9], with limited emphasis on the early stage of identifying TOD nodes as strategic locations for development. Without such identification, TOD initiative risk being fragmented and less effective in achieving sustainable mobility outcomes.

Therefore, this study aims to identify potential TOD nodes in Surakarta City by applyin spatial analysis methods along the BST corridor. The novelty of this research lies in its focus on a medium-sized city context, where TOD potential has been underexplored, and in the use of Geographic Information System (GIS) techniques to map and analyze transit-oriented catchment areas. This finding are expected to provide an initial empirical basis for planning and policy formulation related to TOD development in Surakarta.

RESEARCH METHODS

Study Area

The research was conducted in Surakarta City, Central Java, Indonesia, a medium-sized urban area with a population of approximately 520,000 in 2023 [10]. Surakarta serves as a regional hub for education, culture, and trade, while also experiencing increasing mobility challenges due to urban growth and motorization. To address these challenges, the city introdced the Batik Solo Trans (BST) corridor as the backbone of its public transportation system. The corridor spans strategic routes across the city, connecting central, residential, and peri-urban areas. The Spatial Plan of Surakarta (RTRW 2021-2041) designated TOD zones along the BST corridor as a priority for integrated transport land use development.

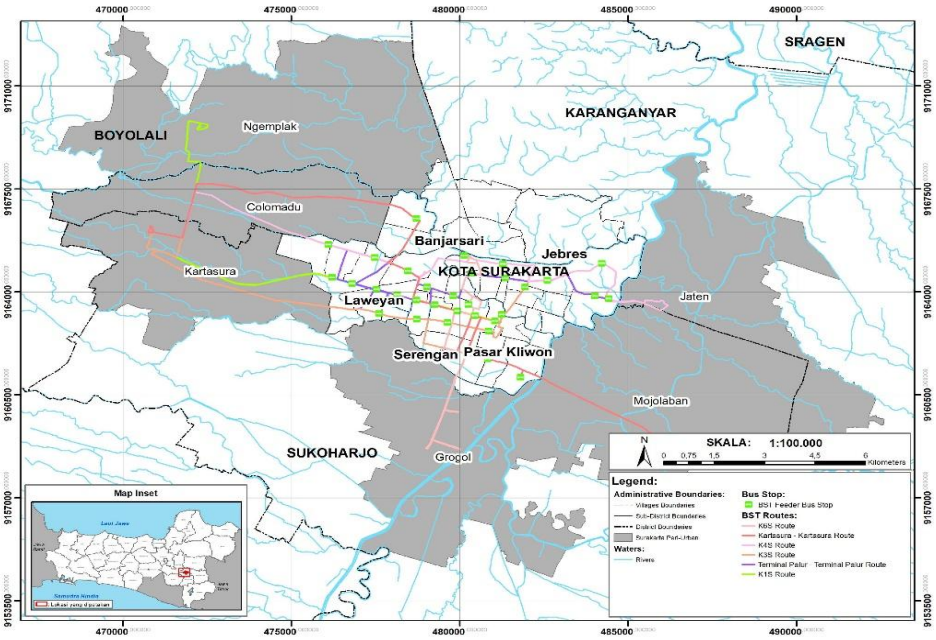

Figure 1. BST Route and Corridor Map in Surakarta

Data Sources

The analysis in this study relied on spatial and non-spatial data to identify and assess potential TOD nodes along the BST corridor in Surakarta. The required datasets were selected to capture both physical characteristics of the urban environment and functional attributes relevant to TOD. Key data include administrative boundaries to define the study area, BST route and stop locations for transit mapping, road networks to assess accessibility and connectivity, and land-use maps to evaluate the diversity of urban functions. All datasets were obtained from authoritative government institutions to ensure accuracy and consistency. The details of the data requirements, sources, and their use in the research are summarized in Table 1

Table 1. Variable Table and Data Requirements

Type of Data	Description	Source	Use in Research
Administrative Boundaries	City Boundary, Sub-District Boundaries	BIG (Geospatial Information Agency, 2022)	Defining study area and spatial overlay
BST Route and Stops	BST corridor and stop locations	Department of Public Works and Spatial Planning of Surakarta City	Mapping and identification of TOD nodes
Road Network	Primary and Secondary Roads	Department of Public Works and Spatial Planning of Surakarta City	Analyzing accessibility and connectivity
Land Use Map	Residential, Commercial, Education, Government, etc.	Department of Public Works and Spatial Planning of Surakarta City	Overlay analysis of use within buffer zone

Methodology

The study focused on identifying potential TOD nodes along the BST corridor using Geographic Information System (GIS) analysis. First, all BST stops were georeferenced and mapped along the main corridor, with ten major nodes selected for analysis based on service coverage and urban significance. An 800-meter buffer zone was then applied around each stop to represent the standard walking catchment area for TOD, as suggested by ITDP and widely adopted in TOD studies. Within each buffer zone, land-use patterns, road networks, and key urban functions including commercial, educational, governmental, and health facilities, were overlaid to assess the relative strategic importance of each node. Finally, based on spatial integration and policy alignment, the ten nodes were categorized as central, intermediate, or peri-urban potentials, providing the empirical foundation for assessing TOD readiness in Surakarta.

The analytical framework combines planning policy review with spatial analysis tools. Policy review ensures alignment with Surakarta's RTRW and TOD principles, while spatial analysis provides a quantitative basis for identifying transit nodes. This dual apporach strengthens the reliability of results and bridges the gap between normative planning and empirical evidence [11].

The process begins with the collection of spatial and planning data, including administrative boundaries, BST routes and stops, road networks, land-use maps, and the city's Spatial Plan (RTRW). These datasets are then proecessed in a GIS environment to conduct buffer analysis the potential TOD catchment area, while the overlay integrates land-use functions, accessibility networksm and policy designations. The outputs are categorized TOD nodes (central, intermediate, and peri-urban), which form the empirical basis for assessing TOD readiness in Surakarta. This framework ensures alignment between spatial evidence and urban planning plicy, strengthening the validity of the identification process.

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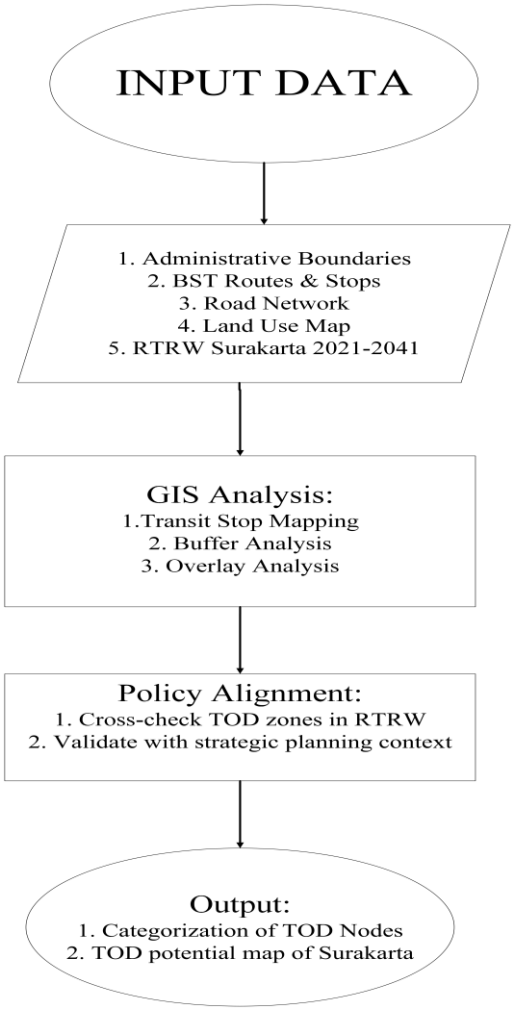

Figure 2. Analytical Framework

Figure 2. illustrates the process of identifying potential TOD nodes in Surakarta City. The analysis begins with input data, cosisting of spatial datasests (boundaries, BST routes and stops, road networks, land use) and planning documents (RTRW 2021-2041 and transportation master plan). These datasets are processed in a GIS through three main steps, which is Transit Stop Mapping, Buffer Analysis with an 800-meter Catchment Area, and Overlay Analysis of Land Use and Key Urban Functions. The spatial outputs are then aligned with policy designations in the city's spatial plan to validate TOD zoning. The final results categorize transit nodes into central, intermediate, and peri-urban potentials, providing a spatial framework for TOD readiness in Surakarta.

RESULT AND DISCUSSION

Results

The Surakarta Batik Solo Transit (BST) corridor consists of several primary stops that serve as potential anchors for TOD development. Through spatial mapping, ten major transit nodes were identified, including Solo Balapan, Purwosari, Solo Jebres, Tirtonadi, Kartasura, Palur, and several intermediate stops along the corridor. These nodes represent a mix of central, intermediate, and peri-urban locations, reflecting the diversity of Surakarta's urban structure, shown in **Figure 3**.

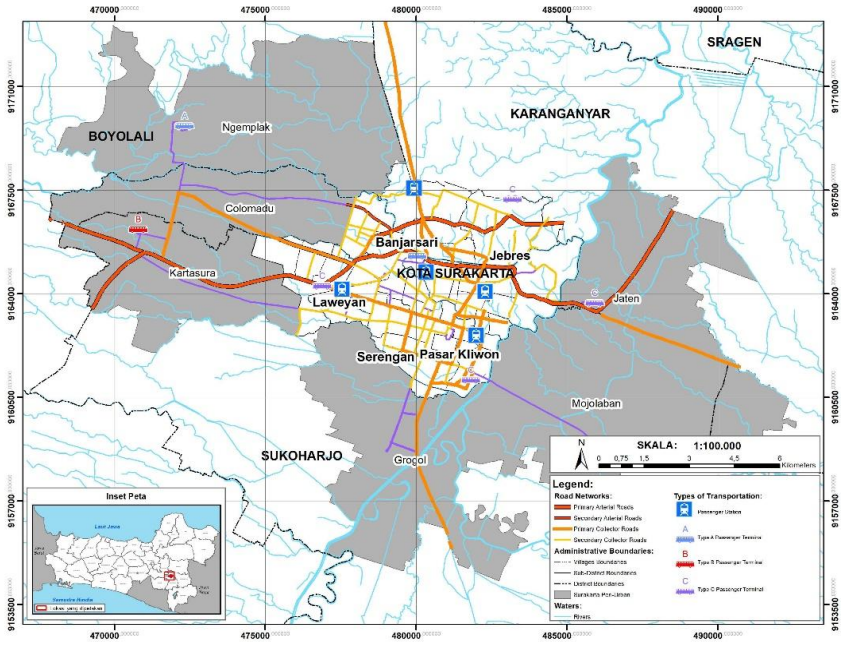

Figure 3. Map of Transit Point in Surakarta

Using an 800-meter buffer around each transit stop, catchment areas were deleniated to represent potential TOD influence zones. Central nodes such as Solo Balapan, Purwosari, and Solo Jebres intersect significantly with dense residential and commercial zones, reflecting strong TOD readiness. Intermediate nodes like Solo Kota Sangkrah, Kadipiro, and Pelangi cover mixed-use areas but with less intensity compared to central locations. Meanwhile, peri-urban nodes such as Semanggi, Palur, Karasura, and Adi Sumarmo Airport encompass larger areas with lower land-use density, reflecting weaker current TOD readiness but strong opportunities for planned expansion.

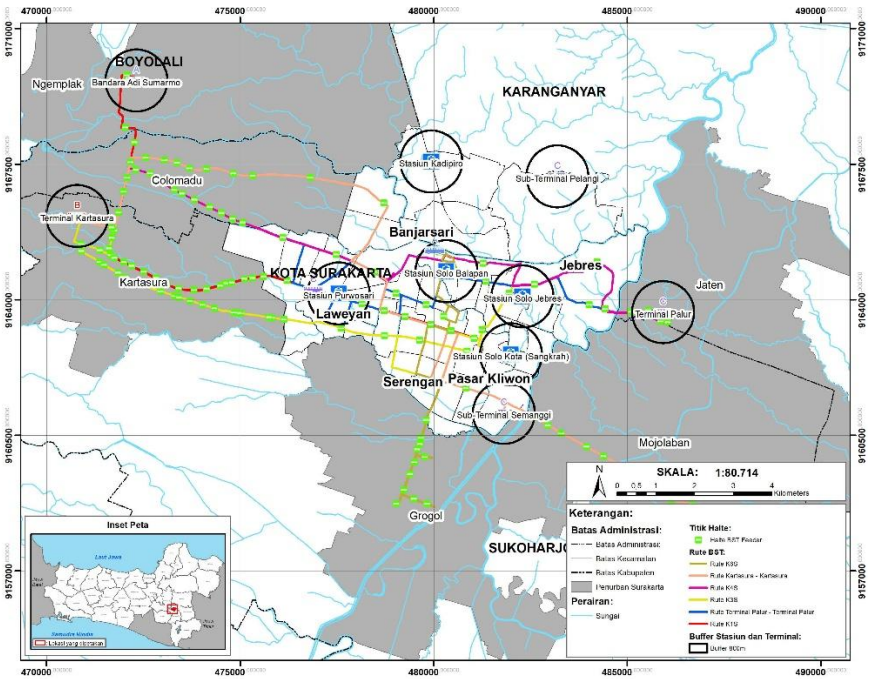

Figure 4. BST Feeder Route Network Map and Transit Service Coverage In Surakarta City

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Overlay analysis based on **Figure 4.** indicates that central nodes are characterized by diverse land use and multimodal connectivity. Solo Balapan functions as the primary railway hub integrated with commercial and service activities, while Purwosari connects western residential areas with the central corridor. Solo Jebres demonstrate strong institutional potential with surrounding educational facilites. Intermediate nodes such as Solo Kota Sangkrah, Kadipiro, and Pelangi providde important links between neighborhoods but still lack the intensity of mixed land use found in central areas. In contrast, peri-urban nodes such as Semanggi, Palur, Kartasura, and Adi Sumarmo Airport are dominated by residential functions and peripheral service, with limited diversity of activities.

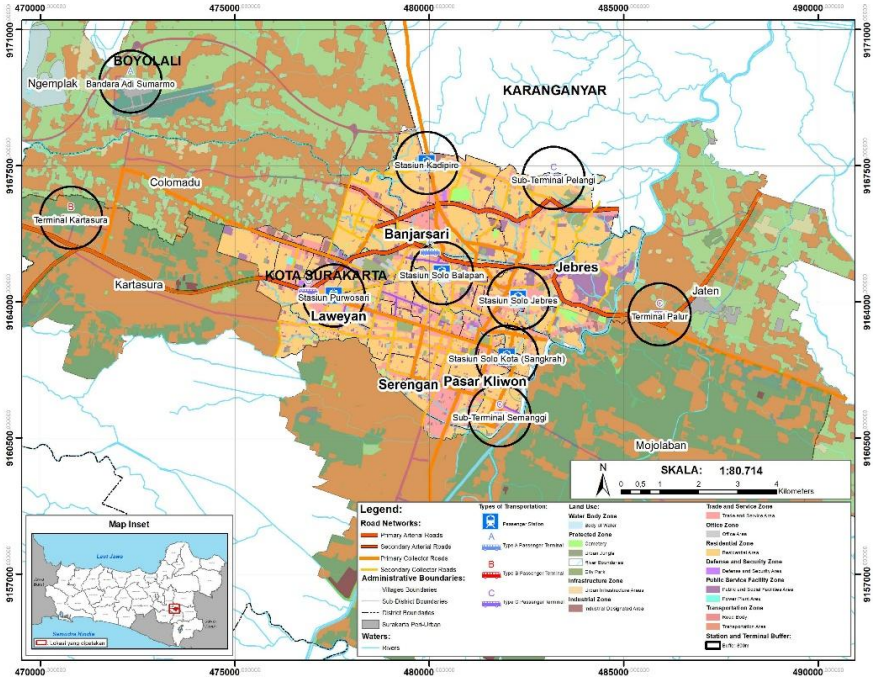

Figure 5. Transit Node Distribution Map And Land Use Characteristics In Surakarta City

Based on **Figure 5** and spatial integration and alignment with the Surakarta City Spatial Plan (RTRW 2021-2041), the ten analyzed nodes were classied into three categories of TOD potential, which is central, intermediate, and peri-urban. Central TOD potential consist of Solo Balapan, Purwosari, and Solo Jebres. These nodes demonstrate the strongest TOD readiness due to their multimodal connectivity and concentration of urban functions. Solo Balapan serves as the city's primary railway hub, integrating regional and local mobility with dense commercial activities in the surrounding area. Purwosari represent another strategic hub, linking western residential areas with the central corridor and benefiting from a mix of commercial, residential, and service functions. Solo Jebres complements the central category as the eastern rail station, characterized by significant educational and community functions that strengthen its role as a local anchor.

Intermediate TOD potentials include Solo Kota Sangkrah, Kadipiro, and Pelangi. These nodes provide important connections between central and peripheral areas but lack the intensity of land-use diversity found in central locations. Solo Kota Sangkrah, located near civic and heritage areas, has moderate TOD potential supported by cultural and community functions. Kadipiro acts as a sub-urban connector node, with residential dominance but gradual growth of commercial and service activities. Pelangi serves as a transitioonal node bridgin central and peripheral corridors, offering moderate accessibility but limited mised-use intensity. These characteristics suggest that targeted interventions could elevate their TOD readiness, particularly through land-use diversification and pedestrian-friendly design.

Peri-urban TOD potentials comprise Semanggi, Palur, Kartasura, and Adi Sumarmo Airport. These nodes are located at the city's periphery and generally display weaker TOD readiness under current conditions. Semanggi, in the southern fringe, is dominated by residential areas with minimal

commercial activities. Palur represents the eastern gateway of Surakarta, strategically located for expansion but lacking land-use diversity. Kartasura, situated in the urban fringe to the west, shows potential due to its role as an educational cluster and sub-urban growth area, although its integration with public transport remains limited. Adi Sumarmo Airport holds strategic significance as a regional tranasport hub, offering opportunities for air-land integration, but the surrounding land-use pattern is currently less diverse. While these peri-urban nodes may not meet TOD criteria today, they provide long-term opportunities for development as the city's growth expands outward.

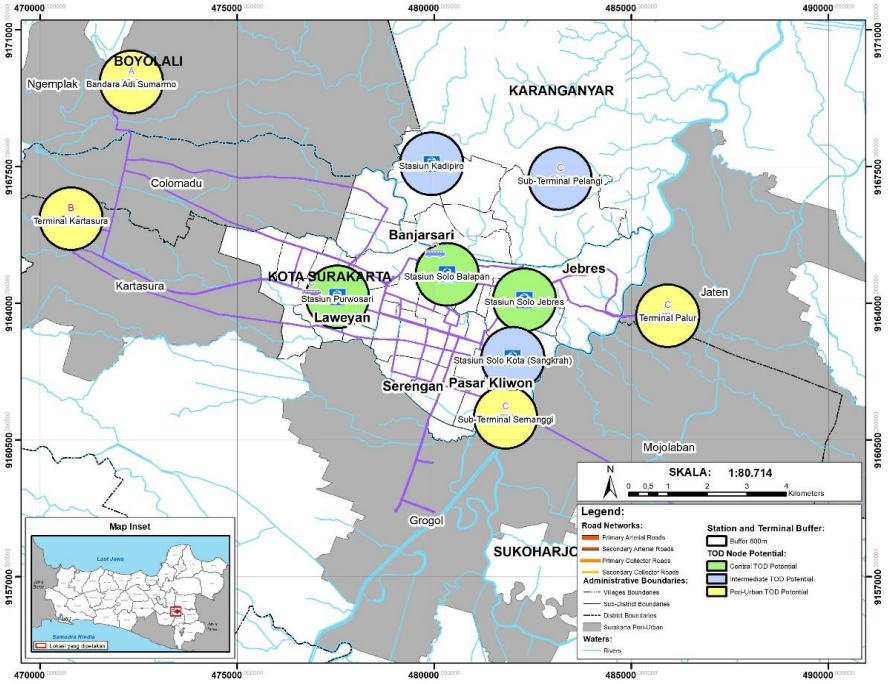

Figure 5. TOD Potential Node Map in Surakarta

This categorization underscores the spatial disparity of TOD readiness across Surakarta's BST corridor. Central nodes are immediately suitable for TOD implementation, intermediate nodes require incremental interventions to enhance their role, and peri-urban nodes should be considered in fututre phases of development planning.

Table 2. Variable Table and Data Requirements

Transit Node	TOD Potential Category	Supporting Characteristics
Solo Balapan	Cenral TOD Potential	Main railway station, dense commercial and service areas, multimodal connectivity
Purwosari	Cenral TOD Potential	Strategic location, mixed land use, strong accessibility to western corridor
Solo Jebres	Cenral TOD Potential	Eastern rail station, educational clusters nearby, strong community functions
Solo Kota Sangkrah	Intermediate TOD Potential.	Civic and commercial activities, moderate land-use diversity

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Transit Node	TOD Potential Category	Supporting Characteristics
Kadipiro	Intermediate TOD Potential	Suburban activity node, growing residential and service functions
Pelangi	Intermediate TOD Potential	Connector between central and peripheral areas, moderate accessibility
Semanggi	Peri-Urban TOD Potential	Southern periphery, dominated by residential use
Palur	Peri-Urban TOD Potential	Eastern gateway, limited diversity, strategic for expansion
Kartasura	Peri-Urban TOD Potential	Western fringe, educational clusters, suburban growth potential
Adi Sumarmo Airport	Peri-Urban TOD Potential	Regional hub for air–land integration, limited surrounding land-use mix

Discussion

The spatial analysis of ten transit nodes along the BST corridor reveals that TOD potential in Surkarata is highly uneven, with central, intermediate, and peri-urban nodes showing distinct characteristics. Central Nodes such as Solo Balapan, Purwosari, and Solo Jebres demonstrate the strongest TOD readiness due to their multimodal connectivity and dense functional mix. This is consistent with recent studies showing that central locations with high accessibility and mixed land uses are the most suitable for early TOD implementation.[12]

Intermediate Nodes such as Solo Kota Sangkrah, Kadipiro, and Pelangi show moderate potential, as they act as connectors between central and peripheral areas but still lack the intensity of land-use diversity. Studies in comparable medium-sized cities highlight that such nodes require tergeted interventions, such as pedestrian-friendly design and land-use diversification to increase TOD viability [13]. Strengthening these intermediate nodes can help distribute urban growth more evenly and reduce pressure on central areas.

Peri-urban nodes such as Semanggi, Palur, Kartasura, and Adi Surmarmo Airport currently exhibit weaker TOD readiness. Their catchment areas are dominated by residential uses with limited service and commercial functions, reflectic typical challenges in peri-urban contexts. However, litature suggests that peri-urban nodes hold strategic potential for long-term TOD if supported by deliberate planning and phased development strategies [14]. For instance, airport-linked TOD is increasingly recognized as a catalyst for regional connectivity, though its success depends on integrated land-use planning and multimodal access.

The Surakarta case aligns with broader findings in Indonesian cities, where TOD readiness varies significantly across different urban contexts. A recent assessment in Jakarta and Bandung emphasizes that while central nodes benefit from existing infrastructure and policy support, peri-urban nodes require stronger institutional capacity and spatial integration to reach TOD standards [15]. Therefore, a phased approach is essential: prioritizing central nodes for immediate TOD development, enhancing intermediate nodes with targeted interventions, and preparing peri-urban nodes as future growth areas in line with the city's spatial plan (RTRW Surakarta 2021–2041).

The results demonstrate that Surakarta's TOD potential is uneven across the BST corridor. Central nodes benefit from historical urban development patterns and higher levels of multimodal connectivity, consistent with TOD literature that emphasize the role of centrality and accessibility in determining TOD success [3]. In contrast, peri-urban nodes reflect challenges common to medium-sized cities, where land availability is higher but supporting function are limited.

This finding aligns with studies in Jakarta and Bandung that highlight the importance of strong policy alignment and urban design interventions in peri-urban areas to realize TOD potential [16]. For Surakarta, prioritizing central nodes for early TOD implementation while preparing peri-urban nodes for phased development may provide a balanced strategy that aligns with the city's spatial plan.

CONCLUSION

This study has successfully identified and assessed the potential for Transit Oriented Development (TOD) along the Surakarta Bus Rapid Transit (BST) corridor by analyzing ten major transit nodes using a Geographic Information System (GIS)-based approach. The application of an 800-meter buffer and overlay of land use, transport networks, and urban functions enabled a systematic categorization of nodes into three levels of TOD potential. The results show that central nodes such as Solo Balapan, Purwosari, and Solo Jebres demonstrate the highest TOD readiness, supported by multimodal connectivity, dense land-use mix, and alignment with the city's spatial plan. Intermediate nodes such as Solo Kota Sangkrah, Kadipiro, and Pelangi exhibit moderate potential, serving as connectors between central and peripheral zones but requiring targeted interventions such as land-use diversification, pedestrian-friendly design, and feeder integration. Peri-urban nodes such as Semanggi, Palur, Kartasura, and Adi Sumarmo Airport currently display weaker readiness but hold long-term strategic value as expansion zones, particularly with the airport node's role as a potential air–land TOD anchor. These findings highlight the uneven distribution of TOD readiness in Surakarta and reinforce the need for a phased development strategy, which is prioritize central nodes for immediate TOD implementation, enhance intermediate nodes incrementally, and prepare peri-urban nodes for long-term integration. The study contributes to the growing body of literature on TOD in medium-sized Indonesian cities by combining spatial analysis with policy alignment. Future research may extend this work by incorporating detailed TOD dimensions, mobility behavior analysis, and stakeholder engagement to design comprehensive TOD strategies for Surakarta.

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