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A Spatial Optimization Framework for Bus Stop Locations: Enhancing Urban Mobility in Jember

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ABSTRACT

Jember's urban area has experienced economic development and has become the third-largest educational hub in East Java. To address the transportation congestion caused by large activities in urban areas, an effective and affordable public transportation system is essential. The coverage of bus stops plays a key role, as evident from their proximity to residential and public areas, as well as the reach of passengers. This research aims to evaluate the coverage of bus stops in the Jember urban area and optimize the locations of new stops. Using the network analyst service area, buffer area, and kernel density, the research defines service coverage within a 400-meter area based on a person's willingness to walk. Additionally, the scoring method used to evaluate the feasibility of bus stops is based on the standardization of bus stop design. The results show that 10 bus stops are not suitable for standardization, while the other nine are moderately suitable. Currently, only 48.7% of the urban area is served by public transport stops. The studies proposed 12 new bus stop locations, which will increase the coverage area to 79.1% and cover 216 out of 273 identified facilities.

1. Introduction

Regional development is closely linked to transportation needs for movement and activities that can potentially cause congestion. Jember Regency has experienced rapid development, supported by increasing economic growth. According to data from the Jember Regency Central Statistics Agency (BPS) (2023), economic growth in 2023 increased by 4.93%. Furthermore, Jember Regency is the third-largest educational city in East Java, with numerous state and private universities. Therefore, movement in Jember Regency will be more effective and efficient if supported by public transportation.

An optimal public transportation network system is characterized by identifying the most effective route network based on community needs and mechanisms that ensure adequate service coverage. Therefore, appropriate infrastructure is crucial, particularly the provision and strategic location of bus stops. Ineffective bus stop location planning can discourage potential users due to limited accessibility to these facilities [1]

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The effectiveness of bus stop services can be evaluated by examining the location of residential areas or public areas around each bus stop to ensure they are easily accessible and encourage public use of public transportation[2]. The distance threshold used in the service area is based on the ideal walking distance to public transportation, which is approximately 400m [3][4] [5].

In the Jember urban area, the availability of bus stops remains limited in terms of service provision; as a result, public transportation passengers often prefer to wait on the roadside rather than using stops located far from their point of origin [6]. This study aims to identify the suitability of bus stop characteristics based on the bus stop design guidelines issued by the Director General of Land Transportation (1996) [5] and evaluate the provision of public transportation bus stops in the Jember urban area in relation to user accessibility. The network analyst service area method is used to analyze bus stop service coverage in relation to residential or public areas and passenger catchment ranges. Additionally, the kernel density method is applied to optimize the placement of new bus stops.

2. Research Method

To optimize public transport accessibility and address the effectiveness of bus stop placement, this study employs a comprehensive Geographic Information System (GIS) framework utilizing multiple spatial analysis methods. While techniques such as buffer, kernel density, and overlay analysis are integrated to evaluate service coverage relative to Points of Interest (POIs), the research specifically emphasizes the use of Network Service Area Analysis. This particular method is critical as it assesses accessibility based on road network topology and actual walking distances rather than simple straight-line metrics, providing a more realistic and robust evaluation of the service catchment areas.

3. Description and Technical

3.1 Literature Review

Public transportation is a mode of transportation provided to the general public through a fare-paying system. This transportation system facilitates the mobility of people traveling in the same direction and destination and operates according to predetermined routes and schedules. Public transportation includes urban modes such as buses, minibuses, and trains, as well as water and air transportation services [7] [8]. Based on the Indonesian Government Regulation (1993) concerning the basic concept of public transportation performance, its assessment consists of effectiveness and efficiency. Effectiveness refers to the assessment of a service system by comparing the results achieved with the impact of the service. On the other hand, efficiency relates to the evaluation of how methods or means are used to achieve the desired results [7]

However the condition of public transportation often causes problems in large cities, especially in developing countries[9]. This problem stems from urban growth, where the increasing demand for public transportation is not accompanied by adequate provision. For every individual traveling, well-integrated facilities are needed to ensure smooth movement from the point of departure to the destination. Residential activity and mixed-use land use around roads lead to increased vehicle movement simultaneously, leading to traffic congestion[10]. Therefore, better traffic management planning and regulation of activities around road corridors are needed to reduce congestion and improve transportation efficiency. One approach is to ensure adequate bus stops[11][12]. In this context, connectivity and accessibility are fundamental principles in transportation planning [6]. Accessibility in urban areas remains uneven, largely due to uneven service coverage within the existing road network [13] such as the limited distribution of bus stops.

A bus stop is a place where passengers can board and disembark public transportation, and where public transportation vehicles stop to pick up and drop off passengers in accordance with operational regulations. The presence of a bus stop facilitates passenger transfers and reduces traffic disruption. Furthermore, according to the Director General of Land Transportation (1996), bus stops aim to facilitate passenger transfers between different modes of public transportation. Therefore, the location of public transportation stops must be strategically planned to effectively meet passenger needs in accordance with bus stop design guidelines. Optimizing the distance between bus stops is crucial for maximizing accessibility, indicating that bus stop configurations that are too dense or too sparse can hinder service effectiveness. [14] [15]

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Bus stop locations can be assessed based on the minimum service distance to the bus stop. The minimum distance to a bus stop refers to the shortest distance a road user can travel to reach the bus stop. The maximum distance used in the service area is based on the ideal walking distance for people to reach public transportation, which is 400 meters [3] [4]. This determination aims to facilitate public access to Points of Interest (POIs), including residential areas, workplaces, educational institutions, shopping centers, and tourist destinations. Points of Interest (POIs) are often used as reference points and are essential components in navigation applications and geographic information systems [16]. Therefore, POIs significantly impact the accessibility and effectiveness of transit stop services. According to a dataset from Victoria's Public Transportation, the average walking travel time from a POI to a public transportation stop is 1 minute, 5 minutes, and 7 minutes, respectively [17] [18]

Meanwhile, bus stop characteristics refer to their features, physical condition, and actual condition. There are Several characteristic aspects that can be used as criteria for assessing a bus stop, as minimum requirements for a bus stop to be considered suitable.

3.2 Research Site

The research was conducted in the urban area of Jember Regency, which includes 3 districts (Kaliwates, Sumbersari, and Patrang). The study focused on public transportation routes and analyzed the spatial distribution of bus stop locations within the urban area. A clearer illustration of the research location is presented in Figure 1.

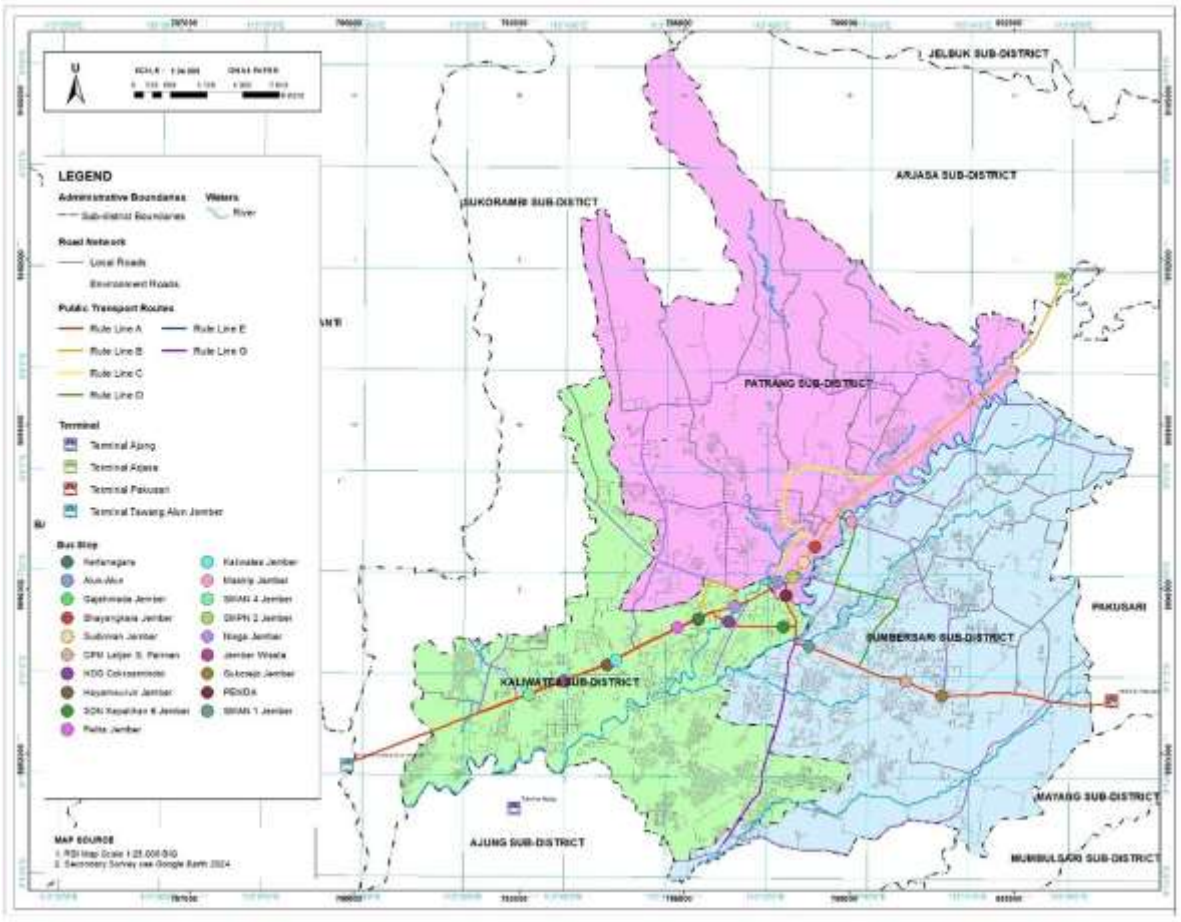

Figure 1: Research Location (research analysis, 2025).

3.3 Data Collection

The data collection procedure was carried out using both primary and secondary approaches. Primary data was obtained through field surveys to identify the characteristics of bus stops. The survey was conducted by observing the physical condition of each bus stop at its respective location within the study area. The parameters used comprised several aspects of bus stop characteristics, according to the Director General of Land Transportation [5].

Meanwhile, secondary data was collected from relevant institutions, such as the local

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government, to obtain information on public routes and administrative boundaries. In a Hungarian study [9], illustrates how researchers used a combination of official statistical data and open source data, such as GTFS feeds and OpenStreetMap. The purpose of this combination is to obtain original data from administrative records, ensuring accuracy and reliability, and to capture real-time updates to reflect the most recent spatial information available. In this study, open-source spatial data were utilised, specifically from Open StreetMap (OSM) and Google MyMaps. Table 1 presents the types of data required for this research, together with their respective sources.

Table 1: Research Data

Required data	Data type	Source
Jember Regency Administration Map	Secondary	Selected Stakeholders
Jember Regency Road Network Map	Secondary	Selected Stakeholders
Bus Stops Location	Secondary	Selected Stakeholders
Points of Interest (POIs)	Secondary	OpenStreetMap and Google MyMaps
Existing condition of the bus stop	Primary	Observation and documentation of the field conditions of the bus stop

3.4 Scoring Analysis

Scoring analysis is a technique used to assign values to each parameter according to its level of suitability or performance. The scores are determined based on predefined criteria,thereby enabling a quantitative assessment of qualitative or categorical data. For instance, scores may be assigned as (1) for low-class values, (2) for medium-class values, and (3) for high-class values [19]. Scoring analysis is applied to classify bus stop characteristics based on the design standards outlined in the bus stop design guidelines, as illustrated in Table 1. The calculation for determining the number of class intervals uses the formula by Sturgess. The formulation is as follows:

$$\boldsymbol{Ki = \frac{Xt - Xr}{k}}$$

Note: Ki = interval value; Xt = highest score; Xr = lowest score; k = number of classses

To evaluate the condition of bus stops in the study area, an assessment was conducted based on the criteria outlined in the bus stop design guidelines. Each bus stop was examined according to key standardisation aspects, and its characteristics were then classified into one of three categories: suitable, moderately suitable, or not suitable. The detailed criteria and classification results are presented in Table 2.

Table 2: Halte Characteristic Classification

Bus Stop Characteristics Based on Bus Stop Standardization	Interval Value	Explanation
Not suitable	17 – 28,3	The bus stop does not fulfill the standardization aspects of the bus stop. Therefore, intervention and repair are needed for the bus stop.
Quite Suitable	28,4 – 39,7	The bus stops adequately fulfills the construction standards. Further attention and follow-up action are required.
Suitable	39,8 – 51	The bus stop fulfills the bus stop construction standards.

3.5 Spatial Analysis

Spatial analysis was employed to determine the optimal locations for new bus stops, using the network service area and buffer area method to assess accessibility and the kernel density method to identify areas with the highest demand concentration.

Buffer analysis and network service area analysis were employed to evaluate the coverage of bus stop services in relation to Points of Interest (POIs). The procedure for conducting these analyses is illustrated in Figure 2. These methods facilitate the assessment of how effectively bus stops serve their surrounding areas.

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Kernel density analysis was employed to identify the concentration of Point of Interest (POI) locations as references in determining the optimal placement of bus stops. The results of the kernel density analysis were classified into four categories based on density levels. The underlying assumption of this method is that the denser the distribution pattern of POIs, the greater the potential for determining optimal bus stop locations.

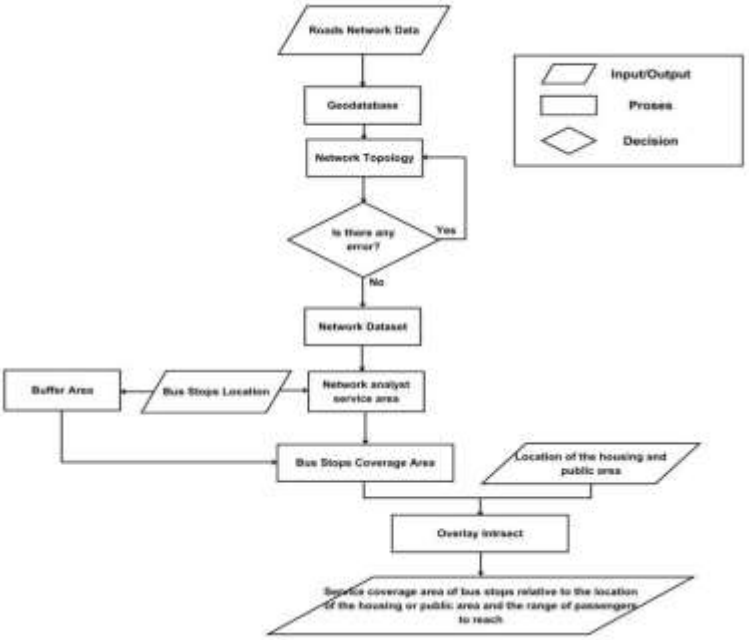

Figure 2: Network Analyst Service Area and Buffer Area Flow Chart (research analysis, 2025).

The kernel density process was carried out using a Geographic Information System (GIS) application. The procedure was initiated through ArcToolbox > Spatial Analyst Tools > Density > Kernel Density. In the Kernel Density window, the input point features were specified using the distribution data of Points of Interest (POIs), after which the analysis was executed. The resulting kernel density output was then reclassified by right clicking the dataset in the Table of Contents, selecting Properties > Symbology > Classified, and setting the number of classes to four.

4. Results and Discussions

4.1 Bus Stop Characteristic

The distribution of public transportation bus stops within the urban area of Jember comprises 19 locations. The characteristics of each bus stop were assessed in accordance with the Director General of Land Transportation [5]. The assessment criteria cover three main aspects: main facilities, additional facilities, and the design and construction of the bus stop.

4.2 Main Facilities

The primary facilities at bus stops include stop identification (number and name traffic signs, timetables, route information boards, lighting, and seating. Field observations of bus stops in urban Jember indicate that the main facilities do not fully comply with the required standards. Several facilities were either unavailable or were often in poor or damaged condition. The information board displaying the bus stop's name was found in damaged conditions, although in some locations the facility remained in good condition. Four bus stops were found to have damaged facilities, namely Cokroaminoto, SMAN 1, SMAN 4, and Sudirman bus stops. One of the bus stop signs was in poor condition, covered with moss to the extent that the symbol was no longer visible. Among the eight bus stops equipped with signs, two were observed in poor condition, specifically at CPM and Hayam Wuruk bus stops. Lighting facilities are available at only five bus stops, namely Cokroaminoto, CPM, Pemda, SMAN 1, and SMPN 2 bus stops. However, several of these are only partially functional. As illustrated in Figure 6, the lighting at SMAN 1 bus stop is non-functional, at "Pemda" bus stop is partially functional, and at CPM bus stop is fully operational.

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4.3 Aditional Facilities

Additional bus stop facilities are intended to support the needs of passengers while waiting. These include public telephones, waste bins, fences, and advertising/announcement boards. However, bus stops in the urban area of Jember lack public telephones, waste bins, and a fence. There are 11 bus stops equipped with advertising/announcement boards. On average, these boards display information about tourist attractions in Jember Regency, along with the public transport services that support related tour packages.

4.4 Design

The design of bus stops is a planning process that includes considerations of passenger capacity and the dimensions of the stop. This encompasses the sheltered area, the floor area per person, and the space required for vehicles to stop.

The standard bus stop size is 4 m x 2 m. By the 19 bus stops observed, 18 met this requirement, while the Mastrip Bus Stop did not, measuring only 3.7 m in length and 2 m in width. According to the minimum standard, the floor area per passenger is 90 cm × 60 cm, with a maximum capacity of 20 passengers (10 seated and 10 standing). A total of 11 bus stops met this minimum capacity requirement: Alun-Alun, Cokroaminoto, Hayam Wuruk, Kaliwates, Kertanegara, Mastrip, Niaga, Pasar Sukorejo, Pelita, SMAN 1, and Trunojoyo.

The minimum standard size for a vehicle stopping is 12 m x 2.5 m. Based on the primary survey, only two bus stops were found to provide designated stopping space for public transport vehicles, namely Pemda and Trunojoyo bus stops.

4.5 The Coverage of Bus Stop Services

The Network Analyst service area method was applied to determine which Point of Interest (POI) locations are within reach of existing bus stops. A 400-metre radius was used, representing the minimum walking distance generally acceptable to passengers. The analysis results indicate the extent of bus stop service coverage.

Figure 3 illustrates 273 points of Interest distributed across the urban area of Jember. These include facilities serving community needs, such as squares, banks, healthcare facilities, offices, markets, educational institutions, accommodations, trade services, places of worship, restaurants, stations, and tourist destinations. The highest concentration occurs in Kaliwates District, which thus serves as the main activity centre of the urban area. Table 3 provides detailed information on service coverage in relation to public areas and housing locations.

Table 3: Service Coverage of Bus Stops in the Urban Area of Jember with a Radius of 400 meters

No.	Subistrict	Public Area and Housing Locations Value	Public Area and Housing Locations Value	
			Affordable	Unaffordable
1.	Kaliwates subdistrict	124	78	46
2.	Patrang subdistrict	60	32	28
3.	Sumbersari subdistrict	89	23	66
	Total	273	133	140

Based on the coverage results obtained using the network analyst service area, 133 out of 273 Point of Interest locations in the urban area of Jember are covered by bus stops within a 400-metre radius. That indicates that only 48.7% of locations are adequately served by existing bus stops.

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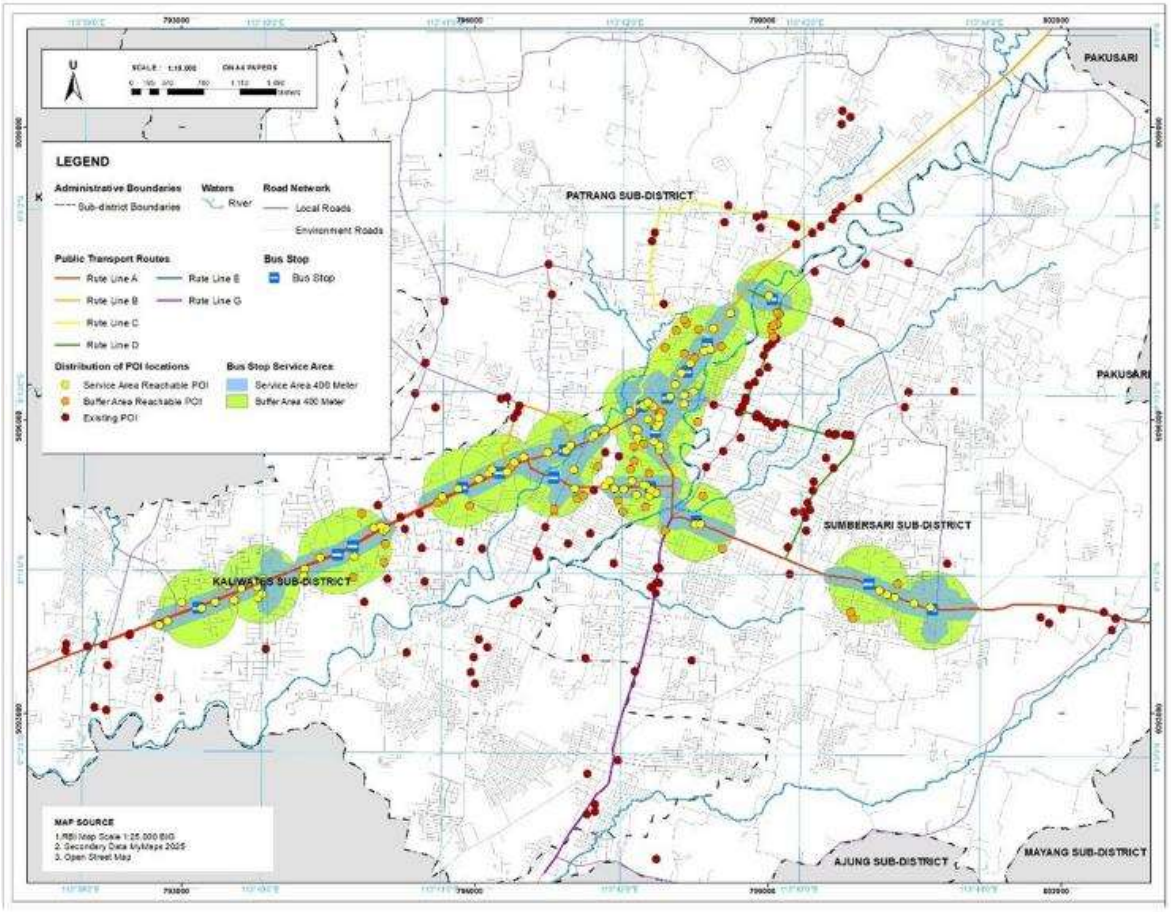

Figure 3: Service Coverage of Bus Stops Towards Point of Interest Locations (research analysis, 2025)

4.6 Scoring Classification of Bus Stop Characteristic

The classification assessment of bus stop conditions was carried out to evaluate whether the existing stops meet the criteria set out in the relevant standards. In addition to accessibility and location coverage, a bus stop can be considered optimal only if it also provides the quality necessary to deliver adequate service to passengers [20]. Table 5 presents the results of the scoring classification of bus stop characteristics in the urban area of Jember.

Table 4: Bus Stop Classification Scoring

Bus Stop Classification Scoring																				
No	Bus Stop	Main Facilities						Additional Facilities						Design and Build						
		Bus Stop Identity		Traffic Sign		Route Information Board		Lighting	Seat	Pay phone	Rubbish Bin	Fence	Advertisement Board	Floor Area /Persn	Bus Stop Siz		Vehicle Stop Siza		Total	Criteria
		Nuber	Name	Bare Color	Embl em	Route	Operating Hours								W	P	W	P		
1	Alun-Alun	1	3	1	1	1	1	1	2	1	1	1	2	1	3	3	1	1	25	Not Suitable
2	Bhayangkara	1	2	3	3	1	1	1	3	1	1	1	1	3	2	3	1	1	29	Quite Suitable
3	Cokroaminoto	1	1	1	1	3	1	3	2	1	1	1	2	1	2	3	1	1	26	Not Suitable
4	CPM	1	3	2	2	3	1	3	3	1	1	1	1	3	3	3	1	1	33	Quite Suitable
5	Gadjah Mada	1	3	3	3	2	1	1	2	1	1	1	1	3	2	3	1	1	30	Quite Suitable
6	Hayam Wuruk	1	3	2	2	1	1	1	2	1	1	1	1	1	1	3	1	1	24	Not Suitable
7	Jember Wisata Keluarga	1	3	1	1	1	1	1	1	1	1	1	1	3	3	3	1	1	25	Not Suitable
8	Kaliwates	1	3	3	3	1	1	3	2	1	1	1	1	1	1	2	1	1	25	Not Suitable
9	Kertanegara	1	3	3	3	1	1	1	2	1	1	1	3	1	2	3	1	1	29	Quite Suitable
10	Halte Mastrip	1	3	3	3	1	1	1	2	1	1	1	3	1	1	3	1	1	28	Quite Suitable
11	Niaga	1	3	1	1	1	1	1	2	1	1	1	3	1	2	3	1	1	25	Not Suitable
12	Sukorejo	1	3	1	1	1	1	1	2	1	1	1	3	1	3	3	1	1	26	Not Suitable
13	Pelita	1	3	1	1	1	1	1	2	1	1	1	3	1	1	2	1	1	23	Not Suitable

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14	Pemda	1	3	1	1	3	1	2	3	1	1	1	3	3	3	3	2	2	34	Quite Suitable
15	SMAN 1	1	1	1	1	2	1	1	2	1	1	1	2	1	2	3	1	1	23	Not Suitable
16	SMAN 4	1	1	1	1	2	1	1	2	1	1	1	2	3	2	3	1	1	25	Not Suitable
17	SMPN 2	1	3	3	3	3	1	2	3	1	1	1	3	3	1	3	1	1	34	Quite Suitable
18	Sudirman	1	2	3	3	1	1	1	3	1	1	1	3	3	3	3	1	1	32	Quite Suitable
19	Trunojoyo	1	3	1	1	1	1	1	2	1	1	1	3	1	3	3	2	3	29	Quite Suitable

Based on the assessment, none of the 19 bus stops in the urban area of Jember met the minimum requirements outlined in the Technical Guidelines for the Design of Public Vehicle Stops in 1996. A total of ten bus stops were categorised as not suitable: Alun-Alun, Cokroaminoto, Hayam Wuruk, Jember Wisata Keluarga, Kaliwates, Niaga, Pasar Sukorejo, Pelita, SMAN 1, and SMAN 4 Bus Stop. Meanwhile, the remaining nine bus stops were categorised as quite suitable, including Bhayangkara, CPM, Gadjah Mada, Kertanegara, Mastrip, Pemda, SMPN 2, Sudirman, and Trunojoyo Bus Stop.

4.7 Optimizing New Bus Stop Location

The determination of new bus stop locations was planned based on the locations of Points of Interest not covered by the service radius of the existing bus stops, as shown in Table 4. The results indicate that current bus stop locations do not fully serve the needs of the movement of community activities. It is in accordance with the statement by [1], who notes that poor bus stop construction can increase the transportation problems, as communities may be discouraged from using public transport due to limited accessibility. The large number of Points of Interest (POI) that are not within the service radius highlights the need to plan additional new bus stop locations, which should be determined according to community mobility demand and the distribution of Points of Interest in the urban area of Jember. Kernel Density analysis within a GIS application was used to determine potential new bus stop locations. This method measures the density of features; in this study, it was applied to the distribution of Point of Interest locations in Jember's urban area that are not covered by the existing bus stop service radius. The results of the analysis are illustrated in Figure 4.

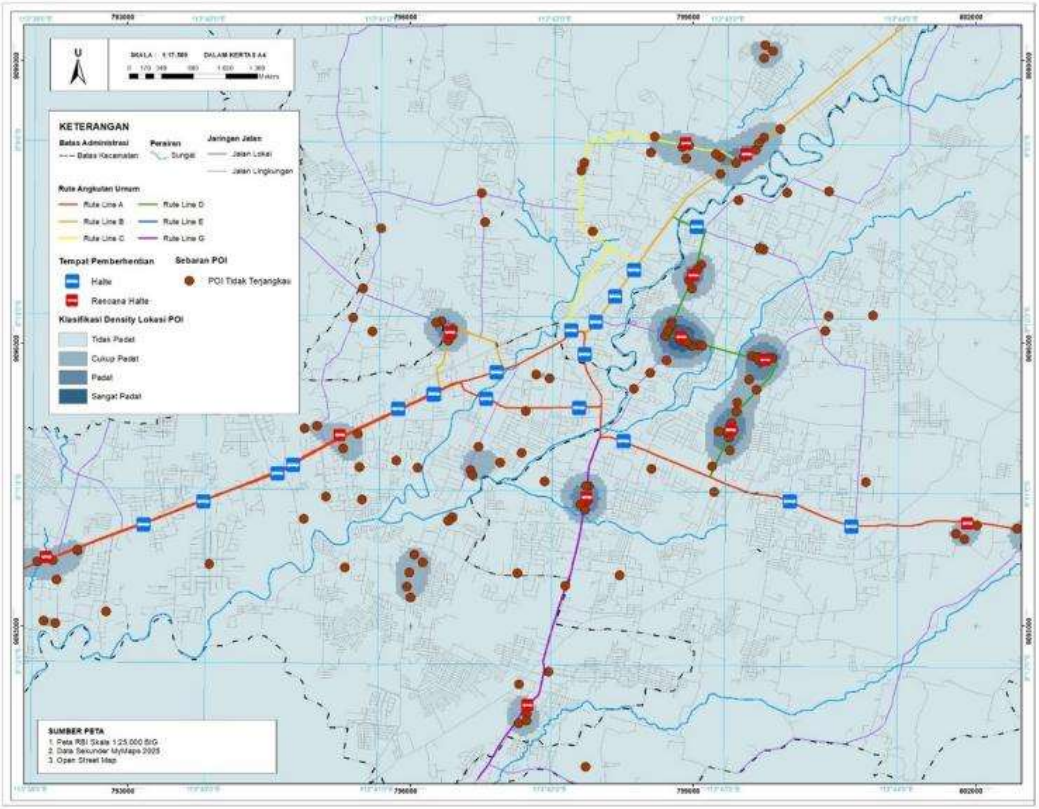

Figure 4: Kernel Density Analysis Result (illustration: authors, 2025).

The results of the Kernel Density analysis were classified into four categories: low, moderate, high, and very high density of POI locations not covered by existing bus stops. These classifications,

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generated within the GIS application, were used to establish priorities for new bus stop placement. Higher Point of Interest locations density indicates greater potential demand, and therefore higher priority for locating new stops. Based on these results, new bus stop locations are proposed at several points along public transportation routes in Jember's urban area, as presented in Table 5.

Table 5: New Bus Stop Location

No	Subdistrict	Road Name	Bus Stop Needed	Location
1.	Kaliwates	Brawijaya	1	50 meter after Brawijaya Alfamart T-junction
2.		Gajah Mada	1	In front of the Bank Indonesia Building
3.		Basuki Rahmat	1	In front of the Tegal Besar subdistrict office
4.	Patrang	Dr. Soebandi	1	In front of Dr. Soebandi University
5.		Brigjen Slamet Riyadi	1	In front of Patrang Resort Police Station
6.		Melati	1	Gebang Traditional Market
7.	Sumbersari	Kalimantan	1	In front of PWI Jember Building
8.		Jawa	2	In front of SMAN 2 Jember
9.				In front of BPD Jember Office
10.		Karimata	1	In front of Hotel Royal
11.		Letjen MT. Haryono	1	50 meters after Sumbersari Resort Police Station
12.		Letjen Suprapto	1	50 meters before Jln. Kahuripan T-junction

Source: Authors (2025)

After determining the optimal new bus stop locations, an analysis was conducted to compare service coverage before and after the new bus stop locations were determined. The results of this comparison between existing and planned bus stop service areas are presented in Figure 5.

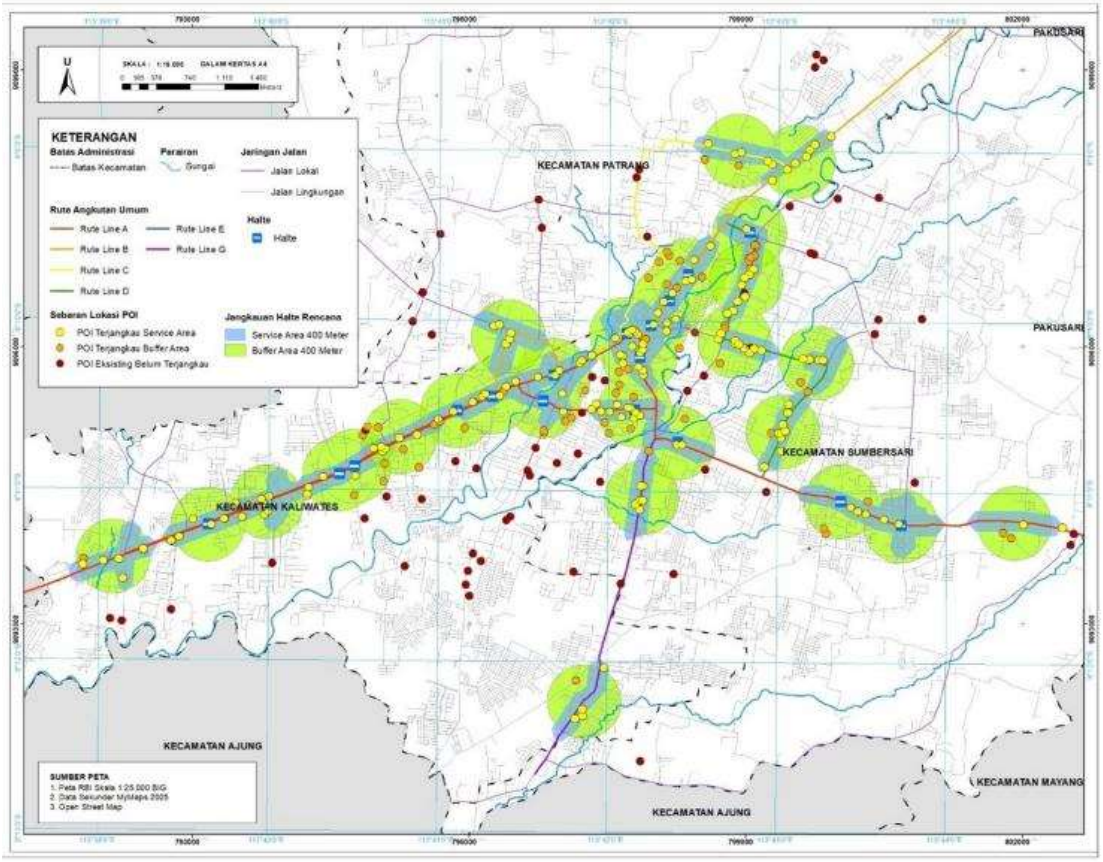

Figure 5: Service Coverage of New Bus Stops in Jember's Urban Area (illustration: authors).

The results indicate an increase in the number of POI locations accessible following the placement of new bus stops. After implementing the planned additions, 216 out of 273 POIs are now within reach, meaning that 79.1% of Jember's urban area is served by bus stops. Table 6 provides a detailed comparison of accessible POI locations before and after the new bus stop implementation.

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Table 6: Comparison of Bus Stop Service Coverage

		Coverage POI	Uncovered POI	Total
Before	POI	133	140	273
	Percentage	48,7%	51,3%	100%
After	POI	216	67	273
	Percentage	79,1%	20,9%	100%

Source: Authors.

At the existing bus stop locations, 133 out of 273 points of Interest (48.7%) were accessible. Following the planning and placement of optimal new bus stops, this number increased to 216 out of 273 points of Interest (79.1%), demonstrating a significant improvement in accessibility. This comparison indicates that adding strategically planned bus stops can increase the number of accessible points of Interest and enhance community mobility for daily activities. These findings align with (Aslan & Kocaman, 2018), who note that the efficiency of public transportation systems can be improved by optimizing bus stop locations in areas that provide greater economic and social benefits to the community.

5. Conclusion and Suggestion

5.1 Conclusion

This study highlights the importance of optimal bus stop planning to ensure both accessibility and passenger comfort. Based on field observations, scoring assessments, and Network Analyst analysis, the suitability of bus stops in urban Jember was evaluated. The assessment of existing bus stop conditions indicates that 10 out of 19 bus stops (52%) are classified as unsuitable according to the standards outlined in the 1996 Technical Guidelines for the Development of Public Transportation, while the remaining nine bus stops (48%) are considered moderately suitable. In terms of service coverage, only 133 out of 273 Points of Interest (POIs) are served by existing bus stops within a 400-metre radius, indicating that just 48.7% of the Jember urban area is currently covered.

The final recommendation for new bus stop locations identifies 12 planned stops, distributed along roads served by public transportation routes in Jember's urban area. A comparison of POI accessibility before and after the addition of these stops shows an increase to 216 out of 273 locations, indicating that 79.1% of the urban area is now served. The proposed bus stop additions are therefore expected to enhance both accessibility and service coverage for the community.

5.1 Suggestion

As urban mobility evolves, future studies should analyze the integration of bus stops with other transport modes, particularly informal transit or ride-hailing services. Researching how these modes bridge the gap beyond the 400-meter buffer could provide a comprehensive view of the "first mile/last-mile" connectivity.

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