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Assessing spatial accessibility of bus stops and user satisfaction with transportation services: a case of Dilla Town, South Ethiopia Region, Ethiopia

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Abstract

Bus stop accessibility is a vital component of a successful transportation system. This study aimed to investigate the network characteristics of bus stop locations and evaluate bus service users' satisfaction. The road networks were digitized from aerial photographs and the locations of the bus stops were collected by Handheld GPS to assess the accessibility of bus stops. Additionally, an administered questionnaire related to service quality was collected to evaluate the bus transportation service quality provided by Dilla University. Network analysis techniques were employed to analyze the spatial distribution and accessibility of bus stops. The bus stop coverage ratio index was determined from the ideal access coverage and the actual access coverage of bus stops. The SCRI result indicates Getsmart Bus stop has the highest value (0.96), suggesting that it has a high level of functionality for its surrounding area. On the other hand, the bus stop with the lowest value (0.60) is 'Molla Golja'. The findings of the study highlighted significant variations in bus stop coverage, indicating differences in accessibility among the stops. The questionnaire survey results showed that passengers were not generally satisfied with the bus service. In summary, the network analysis is useful for identifying areas with low accessibility and areas where improvements are needed.The significance of this study extends beyond providing solely to the needs of Dilla University administrators for creating a more efficient and user-friendly transportation system for their workers and the wider community. It is useful for the Dilla Town Administrative Road Transport Office and other organizations seeking to improve transportation systems.

Keywords/Phrases: Accessibility, Bus stop, Dilla Town, Network analysis, Passengers satisfaction

1 Introduction

Public transportation is an essential mode of transportation in urban areas. It plays a crucial role in fostering sustainable and efficient urban mobility (Ambrosino *et al*., 2016; Pojani & Stead, 2015), providing a viable alternative to private vehicles,and reducing traffic congestion (Liu *et al*., 2017). It promotes social inclusion by ensuring affordable and accessible transport options for all, irrespective of income and ability (Kett *et al*., 2020; Pereira *et al*., 2017).

Access to public transport plays a vital role in an individual's ability to carry out daily activities effectively. Transportation infrastructure and land use systems are essential to model accessibility in a given area (Yigitcanlar *et al*., 2007). Urban transportation planning encompasses information regarding bus stops, road networks, transport routes, and their frequencies (Martínez *et al*., 2014). The absence of bus stops at the peripheries of town leads to humble accessibility on foot (Hernandez & Titheridge, 2016). When bus stopsare easily accessible, it becomes more convenient for people to use public transportation (Borhan

et al., 2019), leading to increased ridership and reduced reliance on private vehicles (Jansuwan *et al*., 2013). This, in turn, can have several positive impacts on the community and the environment. Convenient bus stops encourage a modal shift from private vehicles to public transportation. By ensuring that bus stops are strategically located within communities, close to residential areas, workplaces, educational institutions, and commercial centers, people are more likely to choose buses as a preferred mode of transport (Chakour & Eluru, 2013). This accessibility is determined by how close the passenger's origin or destination is to the nearest transit stop (Pan *et al*., 2017; Wang *et al*., 2011), which can be reached by walking a 400-meter distance as an acceptable standard (Daniels & Mulley, 2013). Overall, the accessibility of Bus stops significantly impacts passenger convenience and their ability to utilize public transportation services effectively (Litman, 2015).

The success of any organization hinges on the quality of services provided. Service quality is the critical link between customer expectations and their actual perception of the service received (Gilaninia *et al*., 2013). Nowhere is this more evident than in the realm of public transportation. Imagine the frustration and disappointment when reliability falters, pushing away both existing and potential clients. Universities, in particular, face the critical challenge of ensuring the reliability and comfort of their bus services, all while ensuring that drivers' attitudes are up to par. These factors, as highlighted by the insightful works of (Md Yusof *et al*., 2014; Osman & Sentosa, 2013), remain constant concerns in the pursuit of excellence.

The Ethiopian Higher Education sector needs significant improvements in service quality despite ongoing efforts by universities (Lemmalodesso, 2012). Various complaints from the university community have emerged, highlighting issues such as inadequate availability and reliability of buses, substandard bus facilities, unsatisfactory attitudes of bus drivers, long waiting times, and a lack of prompt responses to concerns (Oljira, 2022; Phooriphokhai & Jitpraphai, 2016). To ensure the effective utilization of public transportation services, it is crucial to assess the satisfaction of passengers, particularly the Dilla University workers.

While several studies have been conducted in Ethiopia to assess bus service satisfaction (Aniley & Negi, 2010; Belay & Kenei, 2019; M. Girma & Woldetensae, 2022; Lemmalodesso, 2012; Mammo, 2010; Oljira, 2022; Woldeamanuel & Woldetensae, 2021), they have often overlooked the crucial factor of spatial accessibility of bus stops, which plays a significant role in shaping passenger experiences.

By integrating the evaluation of spatial accessibility with service user satisfaction, the study aimed to provide a more comprehensive understanding of transportation services. This approach allowed for a deeper assessment of how convenient and easily accessible bus stops contribute to passenger convenience, time efficiency, and safety. It is useful for the Dilla Town Administrative Road Transport Office and other organizations seeking to improve transportation systems.

2 Materials and Methods

2.1 Description of the Study Area

Dilla town, located between $10^0 14'$ North latitude and $38^0 10'$ East longitude (Minota, 2014), serves as the administrative center of the Gedeo Zone in the South Ethiopia Region. It is situated approximately 359 km away from Addis Ababa city and is renowned for its local coffee industry (Girma & Wube, 2014). 11 bus stop locations in the town are spread along different routes, as shown in Figure 1. Dilla University, a public institution, is also based in Dilla town. As of 2023, the Human Resource Directorate Office reported a total of 5,376 academic and administrative employees at the university.

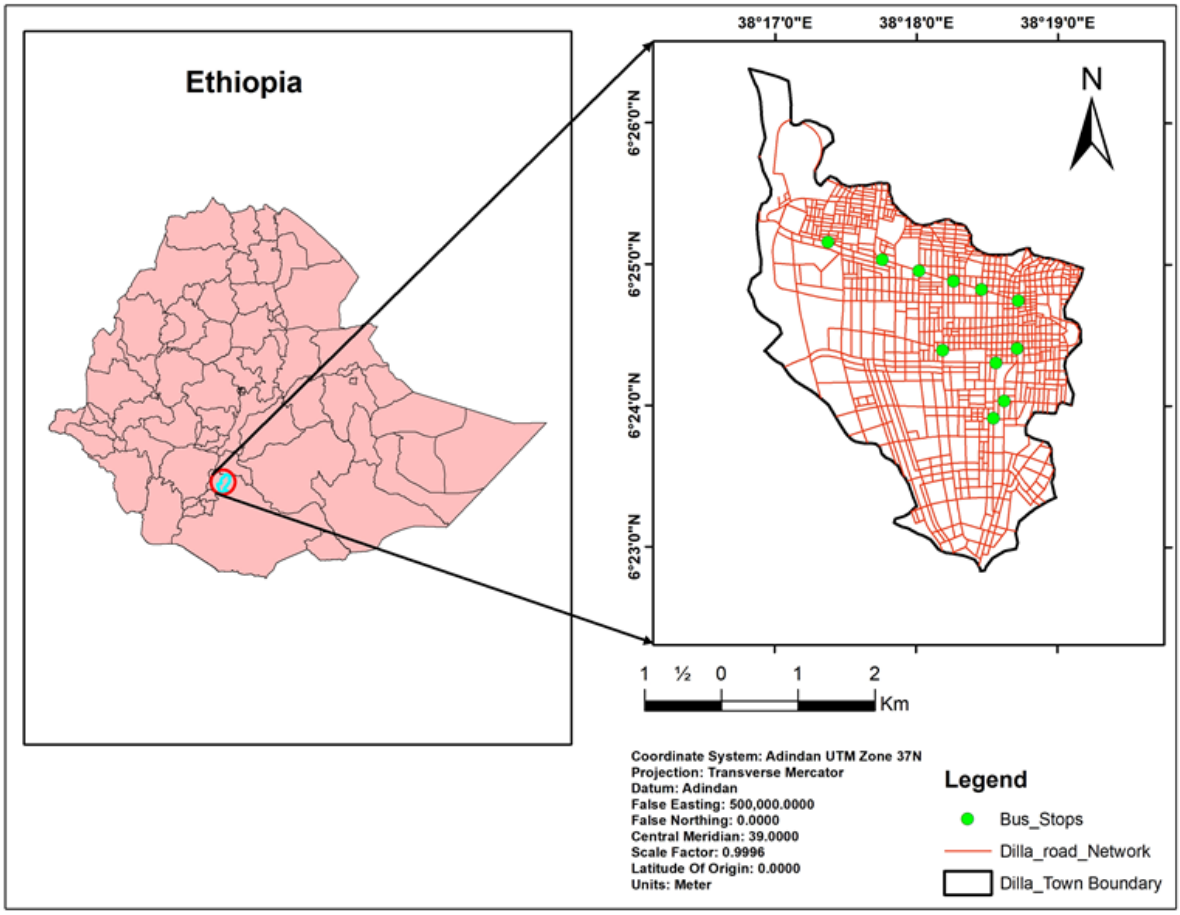

Figure 1. Study area map showing the distribution of bus stops

2.2 Data Source and Method of Data Collection

To assess the accessibility of bus stops in Dilla Town, the survey employed primary data collection techniques. The researcher utilized a Handheld GPS device to gather the coordinates (X and Y) of eleven bus stops located within the town boundaries along the bus route, aiming to assess the spatial accessibility of the stops. The names of each bus stop utilized in this research were taken from prominent landmarks in the respective area. Before digitizing the road networks, the aerial photographs were first georeferenced to align them with the known coordinate system. Additionally, orthorectification was applied toremove distortions caused by terrain relief. The preprocessed aerial photographs were used for the digitization of Dilla Town road networks using ArcGIS Pro. The road network topology was initially created, followed by a correction and validation process to assurance accuracy and consistency. Subsequently, the network dataset was generated by integrating the topologically refined road networks with the gathered GPS points, enabling the determination of the service area.Furthermore, we have developed structured questionnaires to evaluate users' satisfaction with the bus transportation service offered by the university. The details of data used in this study are shown in Table 1.

Table 1. Data and Data Source

Data	Data source	Purpose
GPS Point	Field survey	To locate the existing bus stop
Aerial Photograph	Dilla Town municipality	To digitize road networks (for network analysis)
Questionnaires	Researchers	To assess the user's satisfaction

2.3 Sample Size and Sampling Method

The target population for the study was Dilla University workers, faculty and administrative workers who rely on the university's bus service for transportation. The researchers selected 384 workers out of 5376. The objective was to gather feedback and opinions from experienced bus users working at the university. The participants were chosen using stratified random sampling to address the involvement of both academic and administrative workers in the survey and provided informed consent after receiving a pretested interviewer-administered questionnaire. All statistical analyses were performed using SPSS 22.0 software.

2.4 Determining Accessibility of Bus Stops

Bus stop access coverage is used to evaluate the Bus stop position from the area included in the polygon and the road network lying within the polygon. The Ideal stop access coverage can be determined by creating a simple circular buffer with a standard threshold around each bus stop using the equation (1), which overestimates the coverage access (Foda & Osman, 2010), ignoring the actual road network near the stops. On the other hand, the Actual Area Coverage (AAC) is a complete polygonal representation surrounding all road segments within a 0.4 km radius of the bus stops (Daudu *et al*., 2022). The computation of AAC involves generating service areas using network analysis methods.

$$IAC = \pi r^2 \tag{1}$$

Where: IAC - Ideal Area Coverage and r - Buffer radius; 0.4km.

The Ideal Stop Accessibility Index (ISAI) is determined by calculating the road network density within a circular buffer. This is achieved by dividing the total length of the road network by the area of the circular buffer, as expressed in the equation (2). On the other hand, the Actual Stop Accessibility Index (ASAI) is calculated by dividing the total length of the road network by the area of the generated polygon (Foda & Osman, 2010). This relationship is mathematically represented by an Equation (3).

$$ISAI = \frac{\sum LI}{IAC} \tag{2}$$

$$ASAI = \frac{\sum LA}{AAC} \tag{3}$$

$$SCRI = \frac{ISAI}{ASAI} \tag{4}$$

Where: ASAI- Actual Stop Area Index, ISAI- Ideal Stop Area Index, SCRI- Stop Coverage Ratio Index, LI- Ideal Length of road segments within 0.4km buffer, LA- Actual Length of road segments within 0.4km, IAC- Ideal Area Coverage, AAC- Actual Area Coverage. The overall methodology of the study is presented in the flowchart (Figure 2).

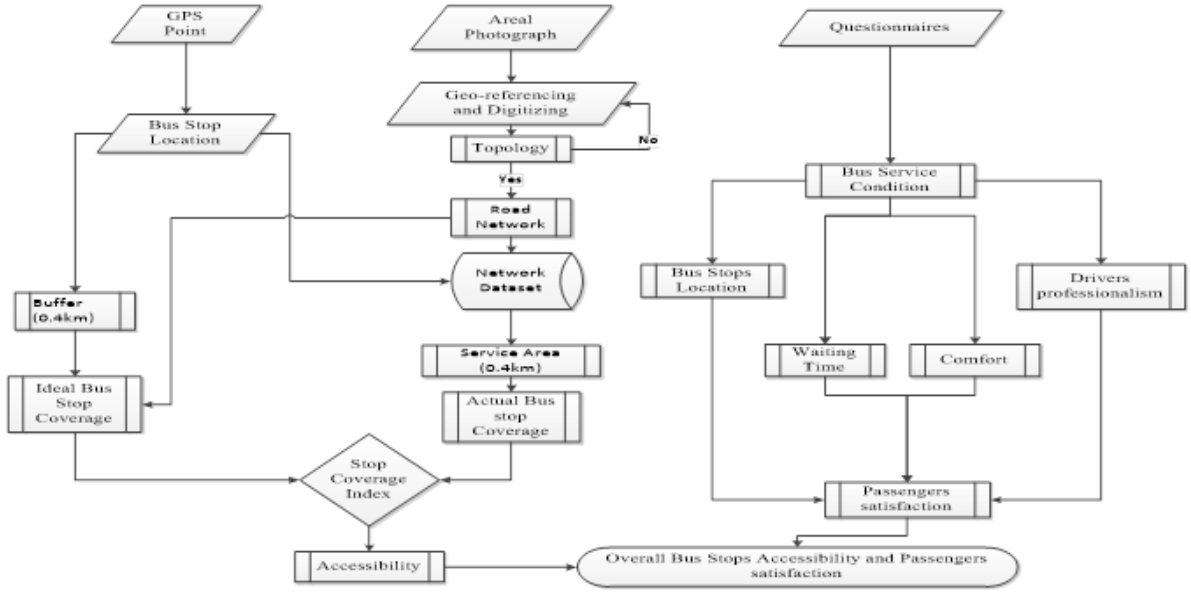

Figure 2. The general workflow of the study

3 Results

3.1 Ideal and Actual Bus Stop Access Index (ASAI and ISAI)

Figure 3a and Figure 3b show the actual service area and ideal service area. A 0.4km buffer was generated around each 11 Bus stop to calculate ASAI. Since the Radius of the buffer is similar, the ideal area coverage is 0.503 km^2. Within this area, the total length of each segment was computed. The total length of access roads across the bus stop is 106.721 km; reachable within the ideal area coverage. The Mazoria station has the highest length of accessible road, which is 12.685 km. On the other hand, the Hospital Bus stop has the lowest length of accessible roads, which is 8.581km compared to other stations. The result of ISAI indicated that Molla Golja station has the lowest index of 15.250 km/km^2 while Mazoria has the highest index (25.219km/km^2).

The Gedeo Zone Higher Court station has the highest actual area coverage (0.427 km^2),whereas the Sunshine bus stop has the lowest area coverage (0.183 km^2). The result of ASAI indicated that Molla Golja station has the lowest index of 15.25 km/km^2 while Mazoria has the highest index (42.401km/km^2). The details of the statistics are found in Table 2.

Table 2. ISAI, ASAI, and SCRI Values for Bus Stops

Station Name	$\sum LI$(km)	IAC(km^2)	ISAI(km/(km^2)	$\sum LI$(km)	AAC(km^2)	ASAI(km/ km^2)	SCRI
Get smart	8.619	0.503	17.135	5.308	0.267	19.843	0.864
Sunshine	10.196	0.503	20.269	5.306	0.183	29.073	0.697
TTC	9.136	0.503	18.164	5.338	0.282	18.928	0.960
Babbo	9.644	0.503	19.172	3.851	0.169	22.730	0.843
Biruk	11.675	0.503	23.211	7.236	0.239	30.229	0.768
Delight	10.042	0.503	19.963	6.120	0.269	22.741	0.878
Hospital	8.581	0.503	17.060	7.579	0.297	25.544	0.668
Gedeo Zone Higher Court	9.857	0.503	19.597	9.360	0.427	21.929	0.894
Lamberet	8.615	0.503	17.128	5.433	0.208	26.181	0.654
Mazoria	12.685	0.503	25.219	11.131	0.263	42.401	0.595
Molla Golja	7.671	0.503	15.250	3.820	0.193	19.776	0.771

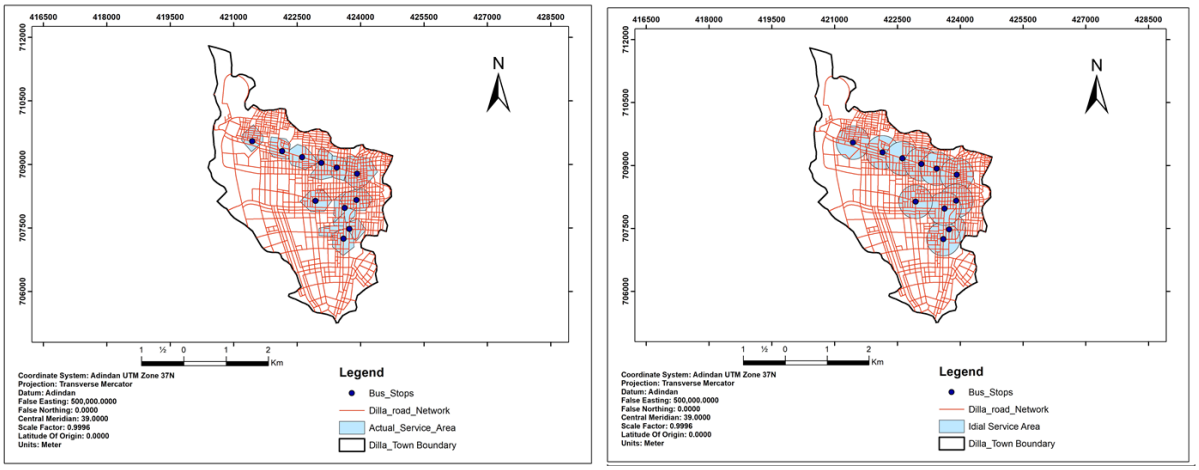

Figure 3. Actual bus stop access (left) and Ideal bus stop access (right)

3.2 Stop Coverage Ratio Index (SCRI)

The SCRI for all 11 stations was calculated by dividing the ISAI by ASAI using the equation [4]. As shown in the (Table 2), the values of SCRI are between 0 and 1. When analyzing the SCRI results for the these stations, it was found that the TTC Bus stop exhibited the highest SCRI value (0.96%). This result indicates that the stationprovides better

accessibility to its surrounding area, making it more convenient for transport users to reach their destinations.

The other stations also demonstrated varying levels of access coverage. For example, the station named "Get Smart" had an SCRI value of 0.864%, indicating a relatively high level of accessibility. On the other hand, "Molla Golja" bus stop had the lowest SCRI value of 0.595% (Table 2), suggesting that it provides lower access coverage when compared to other bus stop locations.

3.3 Analysis for Overall Satisfaction Level

In this study, passengers' satisfaction level was measured by how much they were satisfied with the quality of transportation service experienced at Dilla University. The factors examined were the convenience of the location of bus stops, waiting time, denied entry onto buses due to full seats, and the driver's level of professionalism. The majority of respondents (40.95%) reported that the location of bus stops was very convenient, while a small percentage (1.90%) found it inconvenient, suggesting a need for improvements in this area. The largest group of respondents (45.71%) reported waiting for more than 15 minutes for buses, indicating dissatisfaction with the waiting times. On the other hand, 18.10% of the respondents reported waiting less than 5 minutes (Table 3), which suggests a positive experience in terms of waiting time.

The results indicate that 39.05% of the respondents reported frequent cases of being denied entry onto buses due to full seating. A slightly lower percentage (32.38%) reported experiencing this issue somewhat frequently. However, 20.95% of respondents stated that they rarely encountered this problem, indicating a relatively positive experience. The majority of respondents (43.81%) rated the driver's level of professionalism as good, while a similar percentage (42.86%) rated it as average. A smaller group of respondents (13.33%) perceived the driver's professionalism as poor, indicating room for improvement in this area (Table 3).

Table 3. Passenger's satisfaction for service provision of Dilla University, Dilla, Ethiopia, 2023 (n = 384)

Variables	Category	Frequency	Percent %
Convenience of bus stops	Very inconvenient	99	25.7
	Inconvenient	7	1.9
	Neutral	70	18.1
	Convenient	51	13.3
	Very convenient	157	40.9
Waiting time (minutes)	< 5	70	18.1
	5-10	11	2.86
	10-15	128	33.3
	>15	176	45.7
Denied entry onto buses due to full seats	Very frequently	150	39.0
	Somewhat frequently	124	32.3
	Rarely	81	20.9
	Almost never	29	7.62
Driver's level of professionalism	Poor	51	13.3
	Average	165	42.8
	Good	168	43.8

4 Discussion

In this study, the network characteristics of bus stop locations in Dilla Town were analyzed and evaluated the bus service conditions through questionnaires. In this study, the analysis employed a scale of 0 to 1.0 SCRI, where the bus stop's accessibility decreases as the value approaches 0 and increases as the value approaches 1.0 (Daudu *et al.*, 2022). Based

on the result of SCRI, the bus stop with the highest value (0.960) is the one named 'Getsmart', indicating a high level of functionality for its surrounding area. On the other hand, the bus stop with the lowest coverage index is 'Molla Golja', with a coverage index of 0.595, less functional to its surrounding area when compared to other stations. The finding of this study is consistent with previous studies conducted in Nigeria, in which the highest SCRI value is 0.972 and the lowest is close to 0.163 (Daudu *et al*., 2022). The bus stops on the main road from Dilla University's main campus and the Odaya campus to Dilla Roundabout are better connected and more accessible to other parts of the network. On the other hand, the outlying areas on the road from Molla Roundabout to Chuchu and residential neighborhoods need additional accessible bus stops.

The convenience of the location of bus stops is a crucial factor for passengers (Chen *et al*., 2015; Nguyen, 2020). While 40.95% of the respondents consider the bus stop locations to be very convenient, 25.71% specifies the need for improvements in this area. This result is supported by studies aimed at assessing passengers' satisfaction and revealed that the locations of the bus stops are crucial factors for stakeholders to prioritize the placement of bus stops to satisfy the needs of customers (Litman, 2008; Liu *et al*., 2017).

The maximum waiting time for the bus transportation service should be in the range of 10-20 minutes (Armstrong-Wright, 1993). However, the majority of the respondents (45.71%) reported waiting for the bus more than 15 minutes. However, there is a positive aspect that 18.10% of respondents reported waiting times of less than 5 minutes, recommending that some individuals have had a satisfactory experience in this regard. The dissatisfaction is consistent with previous research conducted in Oslo, Norway, which specifies that reduced reliability and increased travel time are associated with decreased satisfaction with travel experiences (Lunke, 2020). Another study conducted in Addis Ababa city reported that 32.86% of the respondents wait for more than 20 minutes to get service, which is above the standard (Weldeamanuel, 2019)

Another significant issue identified in the results is denyingentrance into buses due to absence of seats. Several respondents (39.05%) stated experiencing this problem regularly, is a challenge that needs to be addressed. While it is positive that 20.95% encountered this issue rarely, efforts must be made to find solutions that minimize instances of overcrowding and ensure that passengers are not left waiting for the next bus due to capacity constraints.

Regarding the driver's level of professionalism, the majority of respondents (43.81%) rated it as good, while a comparable percentage (42.86%) rated it as average. Although these ratings indicate generally satisfactory performance, it is concerning that a notable portion of respondents (13.33%) perceived the driver's professionalism as poor. This signifies the need for continuous training and monitoring to ensure consistent service quality and professionalism among bus drivers (Shaaban & Kim, 2016).

5 Conclusion

This study analyzed the network characteristics of bus stop locations in Dilla Town using a GIS and evaluated the bus service conditions through questionnaires. The study employed the Service Coverage Ratio Index (SCRI) to assess the functionality and accessibility of bus stops. The study found that bus stops located on the main road between Dilla University's main campus and the Odaya campus and those near Dilla Roundabout, had more accessible bus stops than other parts of the network. In contrast, the outlying areas along the road from Molla Roundabout to Chuchu and residential neighborhoods had no accessible bus stop, indicating a lack of access to bus services. This highlights the need to improve bus service in these areas to enhance connectivity and accessibility. These findings emphasize the importance of addressing the shortcomings in the bus service to meet the needs of the community.

This study contributes significant information to the scientific community by analyzing the spatial distribution of bus stops in Dilla Town and evaluating the conditions of bus services. It not only provides information regarding the accessibility of bus stops throughout the town but also offers valuable information about the distribution of bus services in different areas. These findings can serve as a basis for future research and can guide transportation authorities in similar contexts to optimize bus stop locations and enhance overall bus service quality.

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Conflicts of interests

We disclose no conflicts of interests

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