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Analyzing Transit Stop Service Areas Using Geographic Information Systems (GIS): A Case Study of UET Taxila

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Abstract

The University of Engineering and Technology Taxila (UET Taxila), established in 1975 as a campus of the University of Engineering and Technology Lahore, is a leading public university in Taxila, Punjab, Pakistan. With a transportation network spanning approximately 518 square kilometers across Islamabad, Rawalpindi, and Wah Cantt, it provides an economical and efficient transit system for students, faculty, and staff. This study evaluates the service area coverage of transit stops using Geographic Information Systems (GIS) to assess network efficiency, accessibility, and spatial gaps. At the university, 16 buses operate across 16 routes, serving an average of 810 users daily. The analysis defines transit stop service areas based on 5, 10, and 15-minute walking times, assuming a walking speed of 100 meters per minute. Results reveal that 69% of users access transit stops within a walkable distance, while 31% rely on other modes of transport. Among those with walking access, 27% reach a stop in under 5 minutes, 23% within 5 to 10 minutes, and 19% within 10 to 15 minutes. These findings provide valuable insights for optimizing the university's transportation network and supporting future transit planning decisions

Keywords: *Transportation Planning, Transit Stop Analysis, Geographical Information System (GIS), Walking Time, Service Area Assessment.*

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I. INTRODUCTION

Urban population growth is a challenge encountered by many nations around the world. The demand for transport increases rapidly with the rise in city size and population in developing countries, which calls for effective and efficient transportation to meet the needs of the traveling public.[1]. With City populations growing, more pressure is placed on transport infrastructure [2] About 54% of the world's population lived in urban areas in 2014, a substantial rise from 20% in 1950. By 2050, this proportion is projected to reach 60%, adding 2.5 billion residents to the urban population [3].

Buses are an important component of the transport industry, providing access to infrastructure and contributing to social inclusion, thereby serving as a pillar of success. [4] Bus stops are an essential component of a transit user's journey. Access to a bus stop can be determined by how many people, relative to its catchment area, can reach it and how easily it can be accessed using various modes of transportation [5].

Authors of [6] suggested that improvement of the transport system for buses is a potential response to the rise in traffic congestion. Unless concerns related to the safety of bus passengers—both on board and when commuting to the bus stop—and accessibility to bus stops are resolved, the full potential of the bus market cannot be realized [7]. The reason for the socio-economic disparity in the transport sector is primarily due to the rapid growth in urbanization, motorization, and unequal investment in transport and infrastructure planning in the major cities of Pakistan and China [8].

The use of public transport is affected by proximity to passenger stations [9]. Moderate to least accessible stops create the weakest link in the transport system. Not only it is one of the biggest hurdle to follow the existing pattern of fixed-route, but also these bus stops can significantly hamper movement and therefore restrict mobility and potential psychological, physical and cognitive obstacles [10]. However, both bus location and interval affect significantly the efficiency of the transit service and passenger satisfaction, provided the spatial attributes, as they influence travel times [11].

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A Geographic Information System (GIS) approach can be used to assess the accessibility of Stops in the closest bus Routes.[12] GIS-based modelling of transit systems is one of the computer-integrated tool to evaluate the transit system model and to carry out various methods for transit research.[13-15] Transit system modelling GIS applications include transit service area analysis, data allocation and network representation, transit demand, transit delivery, transport system relation, etc. GIS can be used for the analyses of transit-enabling areas and for calculating service level [16] The purpose of this paper is to determine Rapid U.E.T Taxila level of public transport service using the Geographic Information System (GIS).

Most accessibility research concerning transit systems focuses on physical access near a transit stop [17-23]. Some of those studies calculate access to a transit stop from an administrative unit. The use of an administrative unit as a substitute for home of all residents will lead to errors [18]. In terms of travel time, [24] define an accessibility instrument to calculate transit service areas. [25] suggests a transit accessibility measure that includes bus service time as an attribute in GIS.

Bus stop classification is a crucial factor usually based on estimating the covered area and population lying within a reasonable access distance from the bus stop [26] The first objective is to analyze the "walking distances" for transit users to reach the bus stops, the second objective is to classify the number of stops for the whole system. This will help in establishing an optimum transportation network.

The walking speed of 100 m/minute as adopted by [27] is used as a criteria to find transit stop serviceability area and 5, 10 and 15 Minutes Polygons have been generated to Analyze the Area. The goal of this study is to improve transport in a study area by classifying bus stops at A, B, C and D levels. While numerous studies have examined transit accessibility using Geographic Information Systems (GIS), most focus primarily on broader urban networks or rely on administrative units as proxies for user origins, leading to generalizations and potential inaccuracies. Limited attention has been given to micro-level accessibility evaluations, particularly in university-based transit systems in developing countries like Pakistan. Moreover, the specific assessment of walkability zones and serviceability classification of individual bus stops—using fine-resolution GIS network analysis—remains underexplored. This study addresses these gaps by applying a detailed GIS-based approach to evaluate and classify bus stop accessibility at UET Taxila, providing a localized and accurate representation of transit service effectiveness that can inform future planning and optimization strategies.

II. Study Area

With an area of 205344 square kilometers, Punjab is Pakistan's most-developed and populated province. [28] Geographically, it stretches from 31˚1'7.34" N latitude and 75˚22'54.72" E longitude to 27˚42'18.4"N latitude to 69˚19'7.68" E longitude with an altitude that ranges from 77 meters to 1344 meters.[29] The study area includes Islamabad (the federal capital of Pakistan), Rawalpindi, and Wah Cantt.

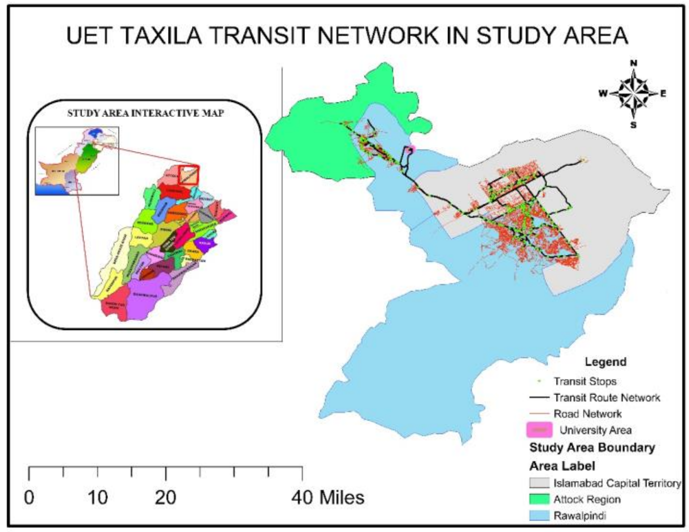

Fig. 1. UET Taxila transit network in study area

The university routes cover nearly 518 km² within the boundaries of these three cities. The study area is bordered by the districts of Attock, Chakwal, and Jhelum. Figure 1 shows the university transit network within the study area.

III. Road Network

The major roads that interlink Wah Cantt, Islamabad, and Rawalpindi include the Grand Trunk Road, Murree Road, Islamabad Expressway, Srinagar Highway, and IJP Road. The major urban and inter-city road network is shown in Figure 2.

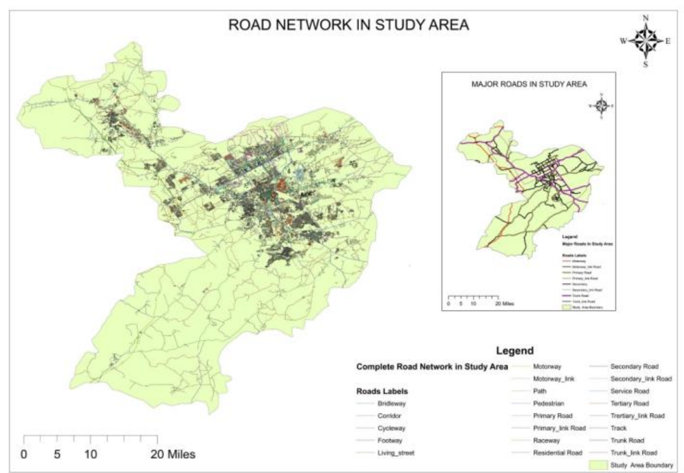

Fig. 2. Road Network in Study Area

IV. Data Acquisition And Gis Analysis

Transit data were collected from the Transport Department of the University of Engineering and Technology, Taxila. These data included transit stop names, lines, and schedules for the development of the network's transit portion. A field survey of 810 transit users was conducted to determine their respective stops and walking distances at each transit stop. Using these survey results alongside high resolution satellite imagery, data for land use and the route network were developed.

A GPS survey was also carried out to obtain spatial data for transit stops. Detailed road network data were generated by digitizing high-resolution satellite imagery. These road network data were used to construct the walking portion of the network by using the length of the roads and a walking speed of 100 meters per minute to calculate walking time for each track section [27]. Network Analysis tool is used to check the serviceability of each stop by generating the 5, 10 and 15 minutes polygons. The complete Research Methodology is shown in figure 3.

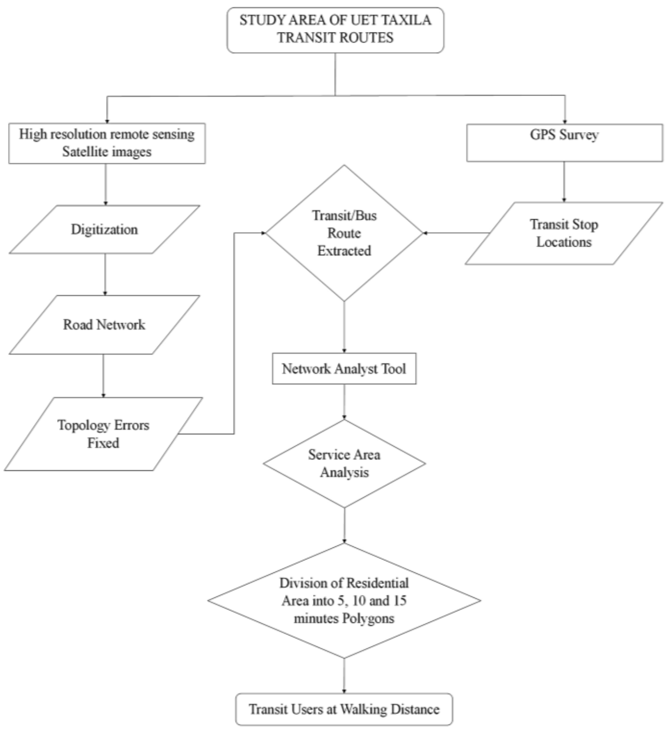

Fig. 3. Methodology Flow Chart

V. Road Network Topology And Network Analysis

Roads and bridges serve as connections to bus stations for passengers. Edge-node topology was incorporated into the road network dataset to construct geometrically corrected network datasets. Geometric errors were eliminated using topological rules such as "must not intersect" and "must not touch interior." Examination of the network addressed various questions related to the linear network, including bridges, ferries, rivers, and utilities. Common applications included road identification, path planning, travel time and distance calculations, identifying the nearest facilities, and measuring area resources (e.g., polygons with 5-, 10-, and 15-minute walking distances). The network dataset included the length of each street section, lane speed, F-node, T-node, F&T minutes, and one-way restrictions to represent the road network linkages in the study area in real time. The dataset with edge-node topology is shown in Figure 4.

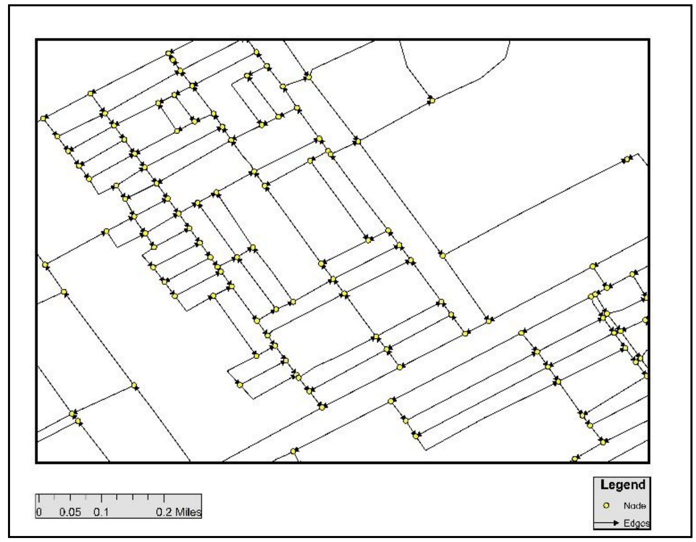

Fig. 4. Road Network Dataset

VI. Results And Discussion

Being one of the most accurate tools for classifying stops and service areas, service area analysis was carried out using road network and pedestrian network data. To evaluate and classify the stops, walking times of 5, 10, and 15 minutes were used. The yellow region in Figure 5 represents areas within a 5-minute walking distance from transit stops. Similarly, the light blue region shows areas with walking times of 5 to 10 minutes, while the dark brown region represents areas with walking times of 10 to 15 minutes from transit stops. The criteria may be modified based on local conditions or geographic context. [30]. The above criteria were used to identify the transit stop service area using the Network Analyst Extension in Arc GIS 10.3. The above criteria were used to identify the transit stop service areas using the Network Analyst extension in ArcGIS 10.3. Figure 5 illustrates the serviceability status of various parts of the study area, including areas with no coverage that lie outside the defined transit time zones.

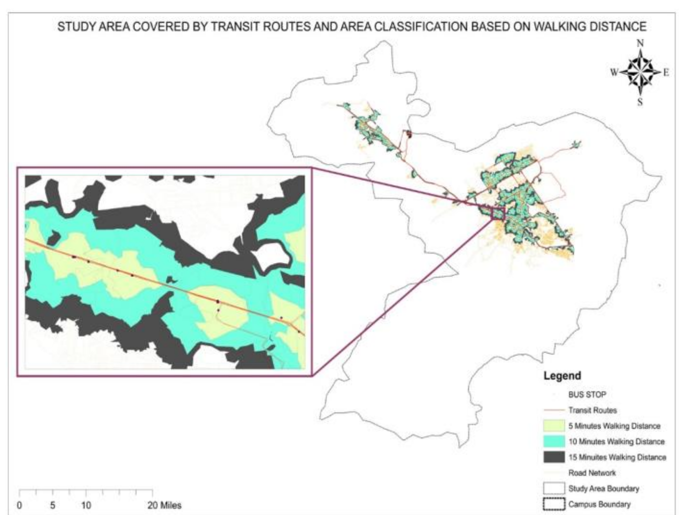

Fig. 5. Classification Based on Walking Distance

It is important to acknowledge that simple walking time polygons may not fully capture real world accessibility constraints. In our approach, Euclidean buffer derived service areas do not account for physical barriers—such as rivers, steep slopes, or gated compounds—that can significantly alter pedestrian routes. As a result, actual walking distances in certain parts of the study area may be under or over estimated. Future work should integrate cost distance modeling or network impedances (e.g., elevation data, barrier layers) to more accurately reflect on the ground walking paths.

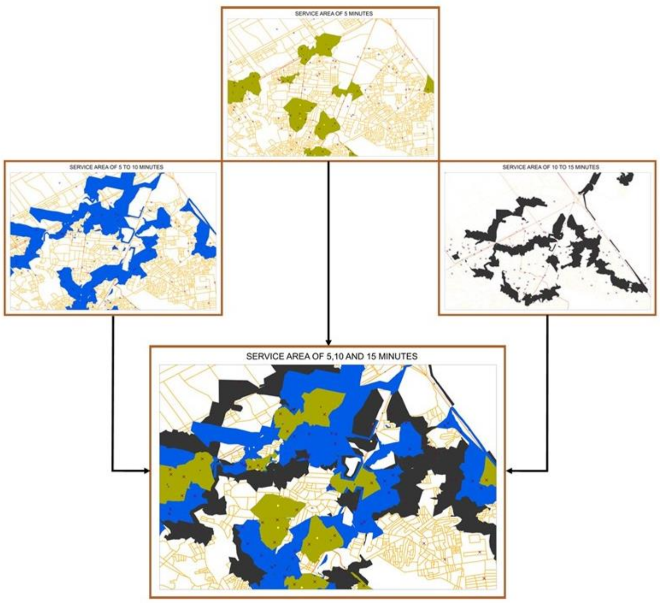

Fig. 6. Showing Polygons of Different Walking Distances

After generating the polygons, the Intersection tool was used between the polygons and transit user data to identify the regions from which transit users actually originate. Many polygons do not serve any purpose, as no transit users come from those areas. To resolve this issue, an intersection of the polygons and transit user data was performed to isolate only those regions associated with actual transit users. The resulting figure 6 shows the 5, 5 to 10, and 10 to 15-minute walking distance polygons through which transit users are coming; this image represents the output after applying the Intersection tool.

To plan the location of bus stops, the main criteria considered are the distance from the origin/destination to the bus stop and the associated walking time. Bus stops are typically placed at the center of a service area, where the radius length indicates service efficiency—excluding factors such as the actual pedestrian route, potential physical barriers, and the density of residential or workplace areas near the stop. The positions of transit users were mapped based on actual walking times, and this data was used to evaluate the effectiveness of each stop. The stops were then graded into four categories, from Level A to Level D, with Level A representing the highest level of service. Table 1 provides a description of each level.

TABLE I. Showing Stops Classifications

Stops level	**Accessibility**	**Description**
Level A	Easily Accessible	All transit users within walking time of 0 to 5 minutes
Level B	Difficult to access	Walking time of 0 to 15 minutes
Level C	Poorly accessible	Walking times of 10 to 15 minutes only
Level D	Accessible via vehicle	Traveling time by vehicle of 0 to 15 minutes

Levels A to D have been represented on the map according to the descriptions provided in Table 1. Various geoprocessing tools were used for this purpose. An intersection between the polygons and home locations was performed to isolate those polygons that are actually serving transit users.

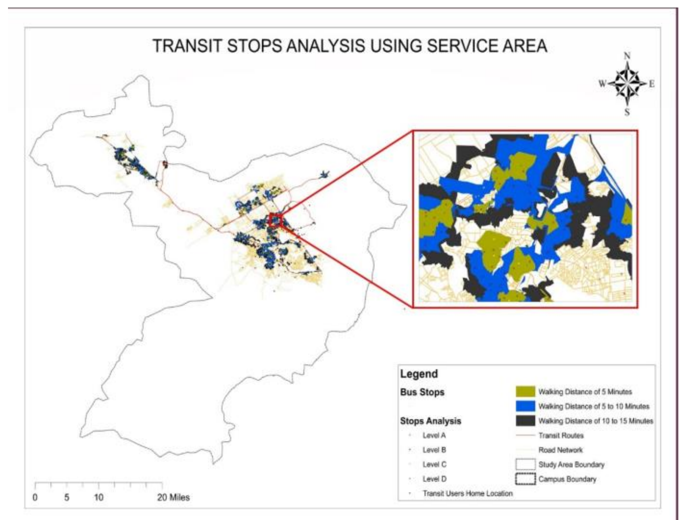

Fig. 7. Transit Stop Analysis Results

This technique was used to display stop levels on the map. The map in Figure 7 presents the final output after applying all geoprocessing tools and shows all stop levels. Both the location and arrangement of bus stops have a direct impact on transit service efficiency and customer satisfaction, as they influence overall travel time [11]. Bus stops in transit networks should also be positioned in an optimal fashion to guarantee sufficient coverage and rapid accessibility for all passengers [9, 11, 31]. The findings shown in figure 8 reveal that only 14% of the stops fall under Level A, which indicates a walking time of 0 to 5 minutes. Conversely, 24% of the stops are classified as Level D, meaning they cannot be reached by walking. Transit users must rely on a vehicle or another mode of transport to access these Level D stops, indicating a significant gap in pedestrian accessibility.

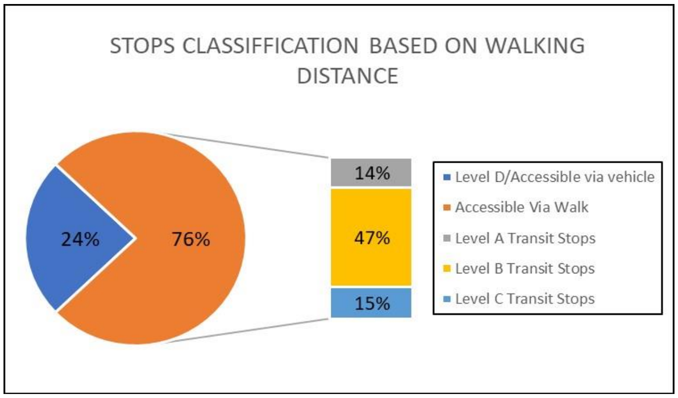

Fig. 8. Stop Classification Results Based on walking Distance

Similarly, using GIS geometric tools, the area covered by 5, 10, and 15-minute walking polygons was calculated. The analysis revealed that approximately 36% of the total area is not covered by transit routes, while the remaining 64% is within the transit service area.

Within this 64% covered area:

- Only 11% falls within a suitable walking time of 0–5 minutes,
- 29% is within a 5–10 minute walking distance, and
- 34% lies within a 10–15 minute walking distance.

Figure 9 illustrates the results of this area-based walking time analysis.

In addition, Figure 10 presents the percentage of transit users according to their walking accessibility. The findings show that 31% of transit users do not have access to any stop within a reasonable walking distance and must rely on vehicles or other transport modes to reach transit services. Among users with access to walkable stops:

- 27% have a walking time of less than 5 minutes,
- 23% walk between 5 to 10 minutes, and
- 19% walk 10 to 15 minutes

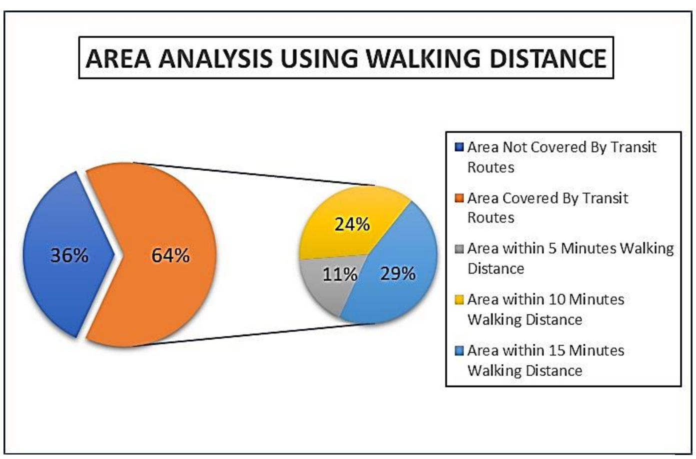

Fig. 9. Showing Results of Area Analysis

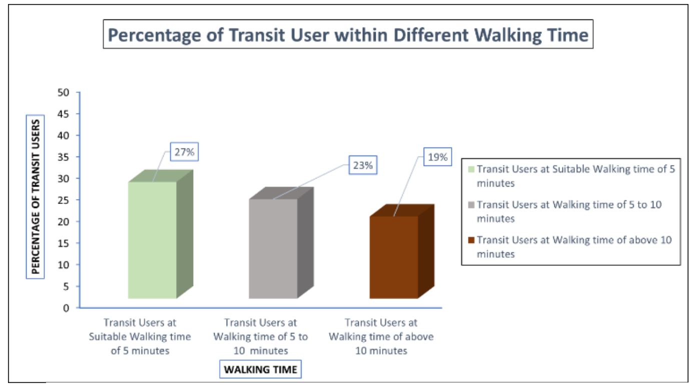

Fig. 10. Proportion of transit users lying in suitable walk time

Our findings align closely with those of García Palomares et al. [12], who reported that no barrier, network based walkability models capture approximately 70% of urban residents within a 10 minute walk to transit in European cities. However, in our university setting, only 50% of users fall within that threshold, highlighting the unique spatial challenges of the UET Taxila network. This comparison underscores the importance of localized GIS analyses and suggests that campus and peri urban environments may require tailored walkability metrics beyond those developed for dense metropolitan regions.

This stop classification framework thus provides a transparent, data driven basis for incremental transit improvements, enabling university planners and municipal authorities to set measurable targets (e.g., increasing Level A coverage from 14% to 25% within two years) and monitor progress via periodic GIS assessments. In doing so, UET Taxila can serve as a replicable model for other campus and peri urban environments grappling with similar accessibility challenges

VII. CONCLUSION

This research demonstrates and validates the effectiveness of Geographic Information Systems (GIS) through a network-based accessibility approach in evaluating the existing transport system of one of the largest educational institutions in the Rawalpindi District of Punjab, Pakistan. The study assesses the serviceability of bus stops based on walking time, classifying them into four levels—with Level A indicating optimal accessibility, defined by a walking time of less than five minutes.

In addition to stop-level analysis, the spatial extent of accessibility was examined to identify the most reachable areas within a reasonable walking distance. The findings reveal that unplanned and inefficient road networks, combined with inadequate spatial transit planning, significantly hinder transit accessibility for users in the study area.

In light of these findings, there is a critical need to redesign and optimize the transportation network and stop locations by focusing on areas with actual demand. Moreover, enhancing the pedestrian and roadway infrastructure, especially in regions with limited accessibility, can play a pivotal role in improving overall transit service. It is also recommended that research institutions and government agencies regularly conduct such spatial analyses to monitor deficiencies, assess user needs, and guide the planning and management of infrastructure in line with evolving public requirements.

VIII. Ethical Approval Statement

The research did not involve direct interaction with human participants, nor did it entail the collection of personal or sensitive information from individuals. Instead, it relied on the analysis of publicly available geographic data and existing transit infrastructure.

Despite the absence of human subject involvement, and in line with standard academic research protocols, ethical considerations were formally reviewed. The research methodology was submitted to the Institutional Ethical Review Committee (IERC) of UET Taxila for clearance. The Committee reviewed the project and determined that formal IRB/ethical approval was not required due to the use of secondary, non-identifiable data and the non-invasive nature of the study.

This ethical approval statement affirms that the research was conducted in accordance with ethical principles and standards, and that the rights and welfare of human participants were not compromised in any way.

References

[1] Goetz, A.R., Transport challenges in rapidly growing cities: is there a magic bullet? 2019, Taylor & Francis.

[2] Cervero, R.J.U.d.f.t.s.c.M.r. and c. infrastructure, Transport infrastructure and the environment: Sustainable mobility and urbanism. 2013: p. 155-182.

[3] (UN-DESA), U.N 810.D.o.E.a.S.A. 68% Of The World Population Projected To Live In Urban Areas By 2050, . 2018. .

[4] Yaakub, N., M.J.W.A.o.S. Napiah, Engineering, and Technology, Public Transport: Punctuality Index for Bus Operation. 2011. 60: p. 857-862.

[5] Proceed Project. Accessibility of bus stops. 2013 March, 2013]; Available from: www.proceedproject.net.

[6] Pulugurtha, S.S. and V.K.J.J.o.P.T. Vanapalli, Hazardous bus stops identification: An illustration using GIS. 2008. 11(2): p. 4.

[7] Hamby, B. and K.J.I.o.T.E.I.J. Thompson, New toolkit provides practical tools to build better bus stops. 2006. 76(9): p. 22.

[8] Ahmed, Q.I., et al., Urban transportation and equity: A case study of Beijing and Karachi. 2008. 42(1): p. 125-139.

[9] Foda, M.A. and A.O.J.J.o.P.T. Osman, Using GIS for measuring transit stop accessibility considering actual pedestrian road network. 2010. 13(4): p. 2.

[10] Project, T.A., Toolkit for the assessment of Bus Stop Accessibility and Safety Easter Seals Project ACTION, S. 700 13th Street NW, Washington, DC, Editor. 2007.

[11] Adebola, O. and O.J.I.E.L. Enosko, Analysis of bus-stops locations using geographic information system in Ibadan North LGA Nigeria. 2012. 2(3): p. 20-37.

[12] García-Palomares, J.C., et al., Walking accessibility to public transport: an analysis based on microdata and GIS. 2013. 40(6): p. 1087-1102.

[13] Yigitcanlar, T., et al., A GIS ‐ based land use and public transport accessibility indexing model. 2007. 44(3): p. 30-37.

[14] Arampatzis, G., et al., A GIS-based decision support system for planning urban transportation policies. 2004. 152(2): p. 465-475.

[15] Ghose, M., A.K. Dikshit, and S.J.W.m. Sharma, A GIS based transportation model for solid waste disposal–A case study on Asansol municipality. 2006. 26(11): p. 1287-1293.

[16] Sutton, J.C.J.T.P. and Technology, GIS applications in transit planning and operations: A review of current practice, effective applications and challenges in the USA. 2005. 28(4): p. 237-250.

[17] Rostampoor, Mahya, Mitra Zamani, and Amir Vaighan. "Combining GIS and analytical hierarchy process for landfill siting, study area: Paveh County in Iran." Journal of Civil Engineering Frontiers 1.1 (2020): 07-15.

[18] Montero-Lamas, Yaiza, Rubén Fernández-Casal, Francisco-Alberto Varela-García, Alfonso Orro, and Margarita Novales. "A spatial statistical approach to estimate bus stop demand using GIS-processed data." Journal of Transport Geography 118 (2024): 103906.

[19] Anjum, Muhammad Touseef, et al. "Accessibility enhancement of mass transit system through GIS based modeling of feeder routes." *Journal of Urban Management* 13.4 (2024): 755-771.

[20] Gutiérrez, J., et al., Distance-measure impacts on the calculation of transport service areas using GIS. 2008. 35(3): p. 480-503.

[21] Somenahalli, Sekhar VC, Michael AP Taylor, and Andrian Wiguna. "Measuring access distance and geographic catchment areas for the bus rapid transit interchange from a longitudinal survey." *Case Studies on Transport Policy* 16 (2024): 101189.

[22] Lovett, A., et al., Car travel time and accessibility by bus to general practitioner services: a study using patient registers and GIS. 2002. 55(1): p. 97-111.

[23] Zhao, F., et al., Forecasting transit walk accessibility: Regression model alternative to buffer method. 2003. 1835(1): p. 34-41.

[24] Cheng, C.-L. and A.W.J.J.o.P.T. Agrawal, TTSAT: A new approach to mapping transit accessibility. 2010. 13(1): p. 4.

[25] Lei, T.L. and R.L.J.I.J.o.G.I.S. Church, Mapping transit ‐ based access: integrating GIS, routes and schedules. 2010. 24(2): p. 283-304.

[26] Foda, M.A., A.O.J.J.o.A.A.f.S. Osman, Technology, and M. Transport, A GIS approach to study the bus transit network accessibility: case study: the city of Alexandria. 2008. 34(65).

[27] Park, J.K. and D.M.J.J.o.K.S.f.G.I.S. Kim, Analysis of shelter service areas according to walking speed using network analysis. 2012. 20(4): p. 37-44.

[28] Ahmad, S., et al., Surveillance of intensity level and geographical spreading of dengue outbreak among males and females in Punjab, Pakistan: A case study of 2011. 2018. 11(4): p. 472-485.

[29] MR, K., et al., Geographical distribution of hypodermosis (Hypoderma sp.) in Northern Punjab, Pakistan. 2012. 18.

[30] Murray, A.T., et al., Public transportation access. 1998. 3(5): p. 319-328.

[31] Holtzclaw, J., Using residential patterns and transit to decrease auto dependence and costs. Vol. 11. 1994: Natural Resources Defense Council San Francisco, CA.