

Assessment of Urban Transportation Systems Regarding Accessibility in Multan City- A Case Study

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Abstract: This research aims to understand and enhance the accessibility level of the public mass transit system in Multan, Pakistan. The public transport accessibility level (PTAL) methodology was adopted, using a GIS analysis tool to generate a map representing PTALs. Factors such as average walking speed, walking time, walking distances to stopovers, and peak-hour bus incidences were considered. The study concluded that locations with small distances to stations, less waiting time for service, and high transit frequency have good accessibility levels. Modified routes were also presented, indicating improved accessibility levels for future planning and development. Future analysts are energized to check accessibility levels by counting unused courses and comparing them with current research. The concept emphasizes the significance of open transport in a city's financial resources and communal value.

Keywords: Public Transport System in Multan, Pakistan, Public Transport Accessibility Level, Transit Frequency

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1. Introduction

Overpopulation and economic growth in urban areas like Pakistan lead to congestion, high accident rates, and environmental degradation. The rise in the middle and upper classes has increased the use of private vehicles, reducing sustainability and environmental impacts. The development of urbanization depends on the adequacy of transport networks, which can lead to social exclusion. This study examines the existing public transport networks in Multan, Pakistan (fig. 4.24 and table 1), and the objective is to determine whether they meet people's needs to reach their desired activity locations. Accessibility is very important in transport planning and is measured using the Public Transport Accessibility Level (PTAL) methodology. Geographical information systems (GIS) are essential tools for transport planning, and their usage plays a crucial role in sustainable operation and system enhancement. Focusing on population increase and insufficient substructure can help us improve mass transit systems and make a more comprehensive environment for citizens.

Table 1: Usual ways of Metro Bus System (MBS) and Veda Bus System (VBS)

Road Name	Roads (Initial and final stations)	Road Name	Roads (Initial and final stations)
FR - 1	Daira Adda to Bakhtaawar Ameen Hospital	FR - 9	Chungi No. 9 to Nag Shah
FR - 2	Suraj Miani to Qasim Fort	FR - 10	Faiz-e-Aam chauk to Chungi no.9
FR - 3	Ghanta Ghar Chauk to Ibn-e-Sina Hospital	FR - 11	Vehari Chauk to Daira Adda
FR - 4	Vehari Chauk to Nag Shah	FR - 9 (B)	Chungi No. 9 to Nadirabad Phatak
FR - 6	Haram Gate to Makhdoom Rasheed	FR - 30	Daira Adda to Sher Shah Bypass
FR - 7	Vehari chauk to 32 Pul	FR - 39	Northern Bypass to Adda Band Bosan
FR - 8	Mohalla Wazir Abad to BCG Chauk	MBS	BZU to Chauk-Kumharan-Aala

2. Literature Review

Public transportation is critical to enhancing fairness and sustainability in metropolitan settings (Almeida Motta et al., 2013) [1]. Factors influencing mobility include age, gender, income, occupation, pedestrian amenities, and mode of transportation. Researchers have developed a variety of methods to quantify transit accessibility [2], including the Local Index of Transit Availability (LITA) method (Rood, 1999) [3], travel cost, besides travel time accessibility index (Schoon et al., 1999) [4], Transit Level of Service (TLOS) (Ryus et al., 2000) [5], and Transit Service Indicator (TSI) (Xin et al., 2005) [6]. Time-of-day transit accessibility study (Polzin et al., 2002) [7], Transit Capacity and Quality of Service Manual (TCQSM) (Kittelson et al., 2003) [8], and Land Use and Public Transport Accessibility Index (LUPTAI) are also used to measure transportation service quality (Pitot et al., 2006) [9]. Transit Accessibility Measure (TAM) is based on utility and traffic accessibility, which includes both the transport accessibility index and the transport dependence index (Bhat et al., 2006) [10]. The Time-based Transit Service Area Tool (TTSAT) assists planners and developers in creating transit-accessible communities by adding passenger information (Cheng & Agrawal, 2010) [11]. The PTAL methodology uses route and service frequency data to integrate local and network accessibility (Mavoa et al., 2012) [12]. Hillman and Pool (1997) [13] introduced ACCMAP, a novel technique for analyzing traffic accessibility.

3. Methodology

Multan city, a business and cultural hub in South Punjab, has experienced significant development in the last three decades. Public transportation, safety concerns, and social and

cultural conventions all have an impact on travel habits. The 28 areas with the greatest activity levels—health, education, shopping, recreation, and employment—are the subject of the study, as seen in Table 2.

A questionnaire study was led at 28 of the highest activity locations, focusing on users' journey purpose, origin, last stop, and means of transport, waiting time, walking time, and perceptions of the existing public transport system. The questionnaire sample is attached in fig. 1 and 2.

Table 2: Highest activity locations in Multan city selected as points of interest.

Point of Interest	Longitude	Latitude
Cantt Bazar	71.439638	30.188661
Cardiology Hospital	71.488955	30.124328
Hussain Agahi Bazar(main market)	71.507134	30.133941
Ghanta Ghar Chauk	71.505026	30.133856
Nishtar Hospital	71.469833	30.153221
BZU	71.523015	30.284523
Children Complex	71.497719	30.130165
K.K Mart Near Tehsil Chauk	71.471501	30.212811
Bohar Gate	71.465217	30.193683
Ibn-e-Siena Hospital	71.592517	30.187332
Chase Up	71.502002	30.194185
Haram Gate	71.469439	30.190217
BCG Chauk Mumtazabad	71.521442	30.092225
Sabzi Mandi	71.546855	30.132319
Lakar Mandi	71.456875	30.183167
Vehari Chauk	71.538252	30.094383
Gulshan Market	71.540542	30.151543
Multan Airport	71.451598	30.138481
DHA Multan	71.503696	30.293704
Railway Station	71.484583	30.113644
Kechahri	71.477166	30.148393
Bakhtawar Ameen Hospital	71.556497	30.242988
Eid Gah	71.478666	30.210198
Tomb of Shah Shamas Sabzwari Tabrez	71.484251	30.200075
MDA Chauk	71.44956	30.210092
Lodhi Colony	71.466361	30.221859
Chungi No.14	71.488794	30.186311
Pak-Arab Fertilizers Multan	71.542997	30.220746

Questionnaire
Accessibility of Urban Transport System (Metro Bus System MBS & Feeder Bus System FBS) of
Multan City

Gender: Male Female

AGE (Years)		OCCUPATION		INCOME (Rupees)		BUS USE		PEAK TIME	
15 to 20		Student		Not Earning		Everyday		07:30 am –	
20 to 30		Businessman		Below 10,000		Once in a Week		08:30 am –	
30 to 40		Public/Private Employee		10,000 to 20,000		Once in a Month		09:30 am	
40 to 50		Worker		20,000 to 30,000		More than once a Month		12:30 pm –	
50 to 60		Others		30,000 to 40,000		Very Rarely		01:30 pm –	
Above 60				40,000 to 50,000				02:30 pm	
				Above 50,000				04:30 pm –	
								05:30 pm	
								07:30 pm –	
								08:30 pm	
								08:30 pm –	
								09:30 pm	
								Other	

1- Purpose of trips mostly made by you.

A- Home	B- Work	C- Education	D- Health
E- Shopping	F- Social	G- Others	

2- Which mode of transportation do you prefer?

A- Metro Bus System (MBS) Only	B- Feeder Bus System (FBS) Only	C- Both MBS and FBS	D- Neither MBS nor FBS
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3- Reasons for Not Using Public Transport (Only answer this question, if you picked answer D of question-2)

A- Accessibility	B- Availability	C- Reliability	D- Affordability	E- Private Vehicle
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4- Selected POI and SAP.

POINT OF INTEREST (POI) =	SERVICE ACCESS POINT (SAP) =
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5- How long does it take in (minutes) to walk to the nearest bus stop? (Walk Access Time) Minutes

6- How long does it take in (minutes) to wait for the bus at station? (Waiting Time) Minutes

Figure 1: Questionnaire Sample Page 1

Q. No	Please assess the following statements according to your perception/opinion.	Rating According to Your Opinion				
		Very Bad	Bad	Neither Good nor Bad	Good	Very Good
1	Perception about safety, pick pocketing and security arrangements related to public transport.	1	2	3	4	5
2	Perception regarding availability of bus stop facilities (LED display, route maps, speakers, sitting benches, shads, bathrooms, drinking water etc.) in the city.	1	2	3	4	5
3	Beneficial for an emergency situation.	1	2	3	4	5
4	Perception about comfort and convenience level (bus condition, seat availability and environment) offered by the Public Transport.	1	2	3	4	5
5	Perception about telecommunications and delivery services that substitute for physical travel.	1	2	3	4	5
6	Satisfaction about available routes of public transport (Metro and Veda bus) in terms of accessibility to your desired locations.	1	2	3	4	5
7	Convenience of transfer (degree of Integration among other transportation systems) offered by the public transport (Metro and Veda).	1	2	3	4	5
8	Perception about public transport frequency (number of buses in one hour).	1	2	3	4	5
9	Perception about operating hours of public transport (Metro and Veda).	1	2	3	4	5
10	Perception about waiting time for bus at the bus stations/terminals.	1	2	3	4	5
11	Perception about travel speed and reaching time at your destination.	1	2	3	4	5
12	Perception about the traffic congestion management which will affect the mobility.	1	2	3	4	5
13	Perception about existing parking space of other transport that will directly or indirectly affect the mobility of selected transport system (Metro and Veda).	1	2	3	4	5
14	Perception about encroachment (commercial activities and movement of hand carts on footpaths/ walkways) in the route of public transport.	1	2	3	4	5

Figure 2: Questionnaire Sample Page 2

The sample size gathered during peak hours was calculated for the study using a sample size calculator. Sixty of the 620 survey forms completed by users involved private automobiles. Origin Pro and MS Excel were used to evaluate the forms. The accessibility index was calculated using the Public Transport Accessibility Level (PTAL) technique, which takes service availability and walk access time into account.

3.1 Method of Public Transport Accessibility Level (PTAL)

The London Borough of Fulham and Hammersmith established the PTAL methodology in 1992 to measure accessibility levels for public transport bus stops within defined catchments.

The methodology involves defining Points of Interest (POI) and determining Pace Access Period from POI to Service Access Point (SAP).

28 of the city's busiest spots were chosen as points of interest for this study. The walking distance from POI to service access points had a Maximum bus/train time to the point of interest of 8 and 12 minutes, to reach this distance, an average speed of 4.8 km/h was used. Concerning a particular site of interest within a given radius, multiple service access points were considered. The Metro Bus System and Veda Bus System routes were taken into consideration for the peak hours (7:30 – 08:30 am) during which valid routes were defined. Given the specific traffic levels within these routes at peak time, the average waiting time was established by considering the frequency of operation.

Total Access Time (TAT) was calculated by combining the walking time from areas of interest to the service access points and waiting time for the chosen transport service to arrive at the service access point. This one aids in ascertaining the relative accessibility for a given place and guarantees the availability of appropriate means of transport.

$$\text{Total access time} = \text{Walk time from POI to SAP} + \text{Average waiting Time at SAP} \quad (\text{eq. 1})$$

The method adopts some casual arrivals, and the regular waiting time is the interval between a passenger's arrival at a station and the arrival of the facility. Each designated route's scheduled waiting time (SWT) is determined by calculating a portion of the headway for the particular route where the service is required.

$$\text{Schedule Waiting Time (SWT)} = 0.5 \times (60/\text{frequency}) \quad (\text{eq. 2})$$

The average waiting time is calculated by adding a reliability factor based on the mode of transport used, with buses having a 2-minute reliability factor and rail amenities having a 0.75-minute factor.

$$\text{Average Waiting Time (AWT)} = 0.5 \times (60/\text{Frequency}) + K \quad (\text{eq. 3})$$

The equivalent door-step frequency (EDF) can be calculated by dividing 30 by the total access time.

$$\text{EDF} = 30/\text{Total Access Time in minutes} \quad (\text{eq. 4})$$

The access time is calculated using the national regular waiting time, assuming the road is accessible at the desired point of interest.

The most suitable route for a specific trip is determined by weighing the most frequent route by a 1.0 weighting factor, while the most suitable route is determined by a 0.5 weighting factor for all other routes. Therefore, for a specific mode of transport, AI_{mode} is determined as:

$$AI[mode] = Largest\ EDF + 0.5 * (Summation\ of\ all\ other\ EDF's) \quad (eq. 5)$$

Total accessibility index (AI) for a solo point of interest is calculated as follows:

$$AI[POI] = \Sigma (AI[mode1] + AI[mode2] + AI[mode3] \dots AI[mode(n)]) \quad (eq. 6)$$

The above formula provides the Public Transport Accessibility Index (PTAI).

With modified assumptions and settings, this study maps PTALs in Multan using the same London PTAL approach. The Multan mass transport administration gathered information on the locations, routes, and frequencies of Veda and metro bus stops, and ArcGIS was used to create the city base map. A shape file for the intended place of interest was created, then routes and station locations were sketched on the base map. In underdeveloped nations, gathering data is difficult, and preliminary research time is expensive. For researchers' convenience, local governments ought to construct shared data centres.

Additionally, the study re-examined PTAL's presumptions about walking speed, dependability factor, peak hour factor, and walking distance. The majority of Multan's roadways lack sidewalks, and some are used for parking, street vendors, and storefronts. The walking pace was reduced by 3.6 km/h to compensate for this discomfort, which is comparable to Ahmedabad, India's strategy, because of comparable geographic circumstances. Table 3 below compares the parameters used to calculate the accessibility index:

Table 3: Difference of parameters applied for calculations of accessibility index.

Considerations	Standards applied to London	Standards applied for Ahmedabad	Standards applied for Multan
Reliability Factor (K) for Bus	2 min	2 min	2 min
Maximum Walking speed	4.8 km/h	3.6 km/h	3.6 km/h
Maximum walking time	8 min	Computed for every point of interest via the existing road network	Computed for every point of interest via the existing road network
Maximum walking distance	640 m		
High-traffic hour	8:15 am–9:15 am	09:30 am–10:30 am	7:30 am–8:30 am

Google Earth is used to measure distances from POI to SAP, and Accessibility Index calculations are made for each of the 28 points. The Punjab Mass-transit Authority provides data for headway, which is then used to measure the frequency of transit on each route, as shown in Table 4.

Table 4: Punjab Mass-transit Authority (PMA) data sheet

Route #	Journey Time	Journey Time (min)	U Turns	Layover	Layover Time for Round Trip Only (min)	Minimum Headway (min)	Fleet Size
Route 001	0:59:58	59.97	0:01:39	0:05:00	6.66	15	10
Route 002	0:25:21	25.35	0:01:23	0:05:00	6.38	20	4
Route 003	0:44:16	44.28	0:02:12	0:05:00	7.21	20	4
Route 003b	1:12:47	72.79	0:04:27	0:05:00	9.45	60	3
Route 004	0:26:07	26.12	0:04:50	0:05:00	9.83	25	3
Route 004b	0:49:41	49.68	0:05:51	0:05:00	10.85	20	7
Route 005	Temporarily Closed						
Route 006	0:58:31	58.52	0:04:00	0:05:00	8.99	30	5
Route 007b	1:08:37	68.62	0:02:30	0:05:00	7.50	20	8
Route 008	0:51:27	51.45	0:02:25	0:05:00	7.43	60	3
Route 008b	1:21:56	81.93	0:01:42	0:05:00	6.70	60	4
Route 009, b,c	1:12:01	72.02	0:02:34	0:05:00	7.57	10	15
Route 010	0:20:35	20.59	0:02:24	0:05:00	7.40	20	4
Route 011	0:41:00	41.00	0:02:23	0:05:00	7.38	20	5
Route 039	0:39:55	39.92	0:08:18	0:05:00	13.29	60	2
Route 030	0:55:04	55.07	0:01:44	0:05:00	6.74	20	7
Route 012	0:26:45	26.75	0:00:40	0:05:00	5.67	20	4
Total =	13:14:03	794.046			129.044		88

3.2 ArcGIS

ArcGIS is a software that visualizes and manipulates geographic information using layer-building maps. It incorporates accessibility indices from PTAL analysis into a GIS spatial database for spatial analysis and graphic characterization. The accessibility index for points of interest and descriptions is spatially joined with attribute data from each point in the survey route. A graphical representation is created using GIS, and interpolation is done using the inverse distance weighted approach.

3.3 Method of Inverse Distance Weighted (IDW)

IDW is a GIS tool utilized for interpolation, predicting missing values for surrounding locations. It assumes that information closer to each other is more identical than farther away. Calculated values have more influence on the closest prediction location. PTAL levels are plotted graphically using range indices. The program creates a map surface with anticipated weights for interpolating nearest locations, accessibility levels in coloured bands, and the local effect of each place of interest.

4. Results and Discussions

4.1 User Responses

The survey data on urban transport usage shows that a majority of users are male (90%) and aged 20-30 years (50%), with significant representation from workers (31.3%) and businessmen (28%). Salary amounts differ, with major group grossing between 20,000 and 30,000 Rs per month (26%). About one-third (33.4%) of users utilize public transport daily, with peak usage times mainly in the morning (24% from 7:30-8:30). The primary purpose of trips is work-related (50%).

Most users rely on the Veda Bus service (52.7%), while a smaller portion uses both Veda and Metro services (18.1%). A notable 66.7% of non-users prefer private vehicles due to accessibility concerns (33.3%) and the absence of issues like affordability or reliability. This data highlights patterns in demographic preferences, frequency of use, and reasons for opting out of public transport.

4.2 User Perceptions

The survey on the Metro Bus System (MBS) and Veda Bus System (VBS) shows a generally positive response regarding safety, comfort, and operational efficiency. Security measures are well-regarded, with 71.25% of users feeling secure, and 80% appreciating the comfort features like air-conditioning and cleanliness. Operating hours and frequency also received favorable responses, aligning well with users' schedules and needs. However, bus stop facilities such as seating and LED displays received mixed feedback, with 47.5% expressing dissatisfaction, and emergency preparedness was a significant concern, as 58.75% rated it poorly, citing inflexible schedules. While MBS avoids congestion with dedicated lanes, VBS faces issues on shared routes, affecting users' experience. Additionally, integration with other transport is viewed positively, yet parking around VBS and encroachment along routes are areas of concern.

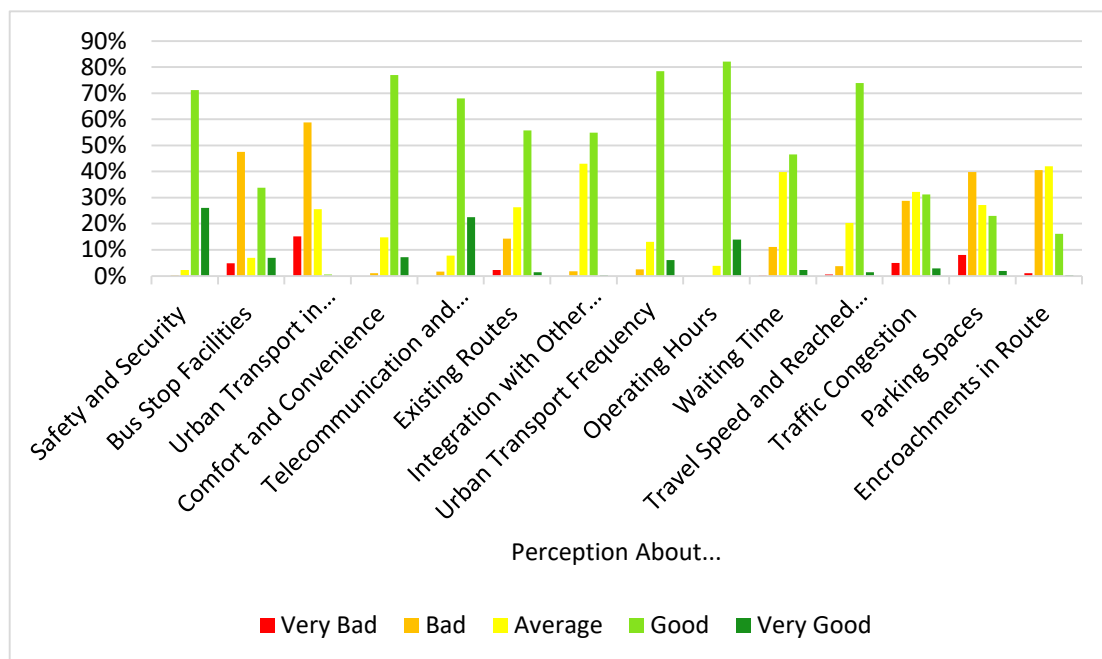


Figure 3: A bar graph showing all the responses from questionnaire about user's perception.

4.3 All points of interest's accessibility levels using the PTAL model

Figure 4 uses GIS to display the service access points (SAPs) along the routes of two urban transportation systems: the Veda Bus System and the Metro Bus System. The stations or terminals are regarded as service entry points. The following GIS-based map displays all of the information on SAPs. While some sites of interest only have one SAP, some have many SAPs.

Figure 5. Displays the chosen points of interest (POIs). Based on the fact that they encircle every route in the Metro Bus System and Veda Bus System, the locations of interest were chosen. High-density locations such as retail centres, educational institutions, commercial buildings, marketplaces, historic recreational sites, etc., are examples of selected points of interest.

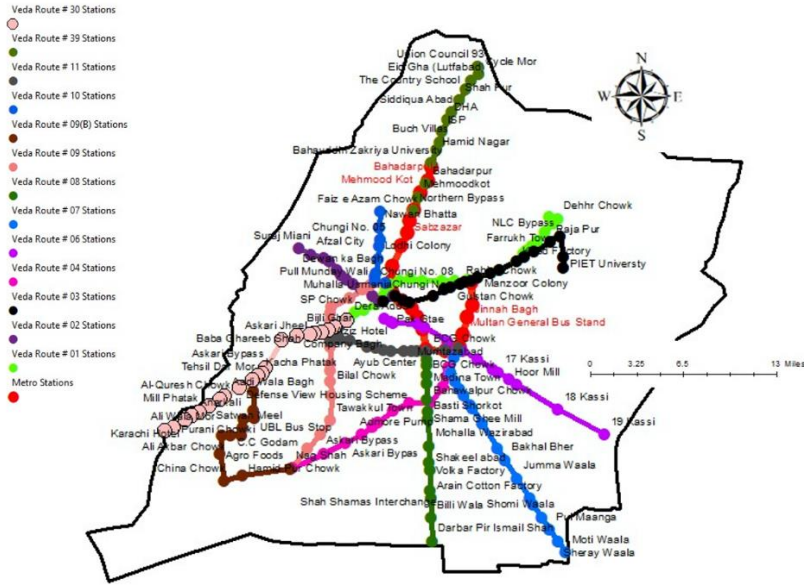


Figure 4: The Veda bus system network and the Metro bus system both display every Service Access Point (SAP).

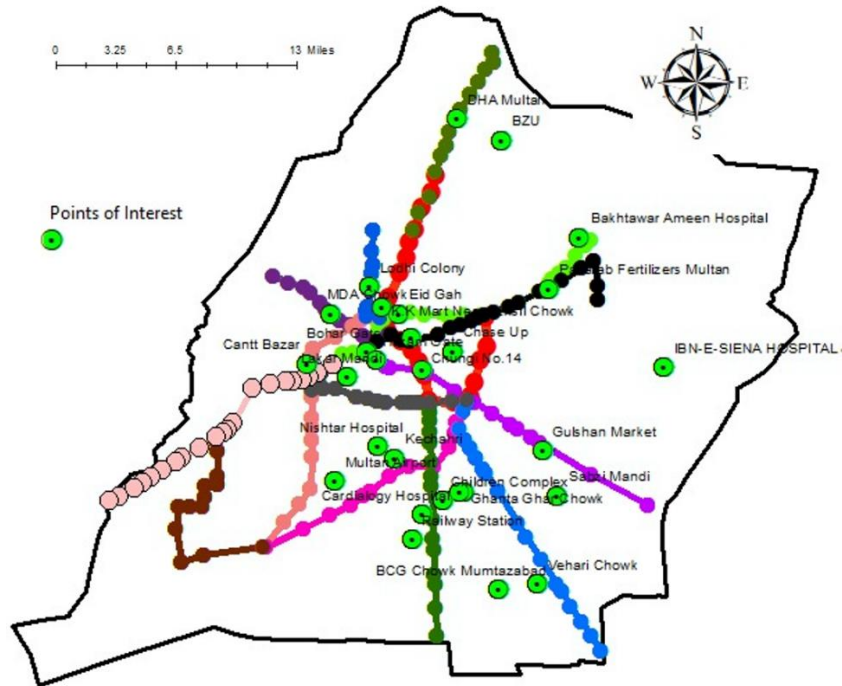


Figure 5: All Points of Interest (POIs) are shown by the Veda bus system network and the Metro bus system.

4.4 Using PATL analysis, the accessibility index of every site of interest (POI)

The Cantt Bazar and Multan Cardiology locations are accessible via the FR-09 and FR-01 Veda routes, respectively, with short distances and reasonable AI values, reflecting efficient accessibility. Similarly, Ghanta Ghar offers multiple routes (FR-01, FR-03, and Metro) that increase travel options, though the distances and route frequencies vary, resulting in different

AWT and TAT values. Longer distances are seen with locations like Lakar Mandi, where Veda routes FR-01, FR-09, FR-11, and FR-30 provide multiple options with distances up to 1500 meters. Consequently, these routes have higher TAT values, affecting the AI, indicating a lower accessibility index due to longer travel and wait times. For instance, BZU Multan & Chase Up shopping Centre are rather benefited by the metro routes where exclusively higher frequency classes having TAT values are available.

The POIs, such as Vehari Chauk, Gulshan Market, and Pakarab Fertilizers, which are surrounded by both metro and Veda routes, have different AI scores because of differences in both frequency of service and distance factors. The analysis also reveals that with increasing metro operating frequencies and travel distances, AWT reduces and AI increases, meaning improved accessibility. The accessibility scores of the POIs vary significantly within the extreme range; some POIs are easily accessed through frequent metro transport routes providing convenient travel means, while other POIs are accessed through Veda services, where most of the POIs earn significantly lower accessibility scores due to the extra distances that are covered and infrequent bus facilities.

The table below shows how PATL model periods are used to compute accessibility index (AI) values. Table 5 displays the individually determined AI values for each Point of Interest's single or multiple service access points.

Table 5: All points of interest (POI) accessibility index (AI) based on PATL study.

POI	Mode of Travel	SAP	Route No.	Distance (D) m	Bus Frequency (per hour)	Weighting factor	Walk Time (WT) min $D/3.6*60$	AWT (min) $0.5*60/f+2$	TAT (min) $WT+AWT$	EDEF 30/TAT	AI
1. Cant Bazaar	VBS	Bomanji Square Veda Bus Station	FR-9	300	3	1	5	12	17	1.76	1.76
15. Lakar Mandi	VBS	Daira Adda Veda Bus station	FR-01	1100	3	1	18.3	12	30.3	0.99	0.99
		Railway Veda Bus station	FR-09	1500	3	1	25	12	37	0.81	0.81
			FR-11	1500	2	0.5	25	17	42	0.71	0.36
		Deda Adda Veda Bus station	FR-30	1100	2	0.5	18.3	17	35.3	0.85	0.42

4.5 Accessibility index (AI) and GIS-analysis

The equations used to compute the AI are shown in Table 5. Table 6 below provides the computed round-off PTAL values for each POI.

Table 6: Values of the Accessibility Index of all POIs

POI No.	Point of Interests IDs	AI
1	Cantt Bazar	1.8
2	Cardiology Hospital	2.4
3	Hussain Agahi Bazar (main market)	3.7
4	Ghanta Ghar Chauk	4.8
5	Nishtar Hospital	1.3
6	BZU	4.7
7	Children Complex	2.5
8	K.K Mart Near Tehsil Chauk	5.6
9	Bohar Gate	1.3
10	Ibn-e-Siena Hospital & Research Institute	1.7
11	Chase Up	3.9
12	Haram Gate	1.7
13	BCG Chauk Mumtazabad	7.6
14	Sabzi Mandi	2.9
15	Lakar Mandi	2.6
16	Vehari Chauk	8.7
17	Gulshan Market	2.2
18	Multan Airport	1.7
19	DHA Multan	0.9
20	Railway Station	3.3
21	Kechahri	2.4
22	Bakhtawar Ameen Hospital	2.4
23	Eid Gah	6.3
24	Tomb of Shah Shamas Sabzwari Tabrez	3.8
25	MDA Chauk	1.7
26	Lodhi Colony	1.6
27	Chungi No.14	7.5
28	Pakarab Fertilizers Multan	2.8

Because there are so many homes, hospitals, marketplaces, and companies in the city centre, it has the greatest public transportation system in Multan. However, because there aren't any Service Access Points or other services nearby, accessibility is low. As seen in Fig. 6, some locations, including Vehari Chauk, BCG Chauk, Chungi No.14, Eid Gah, K.K Mart, BZU, and Ghanta Ghar, have high accessibility because of their numerous service access points, lower wait times, and closer proximity to centres of interest.

Figures 7 and 8 depict suggested metro bus routes and Veda bus routes with hash lines. Along Bahawalpur Road, the Metro bus route (red line) extension begins from BCG Chauk and ends at Bahawalpur Chauk. The red line segment from BCG Chauk to Kumharanwala Chauk should be absorbed by the Orange Line, forming a circular mass transport network. Beginning at Kot Rab Nawaz, the Blue Line travels via Multan Airport, Vehari Chauk, Ghanta Ghar Chauk via Haram Gate, and Kalma Chauk before arriving in Mumtazabad. The Railway Station is where the FR-12 VBS route begins, and Multan Airport is where it ends.

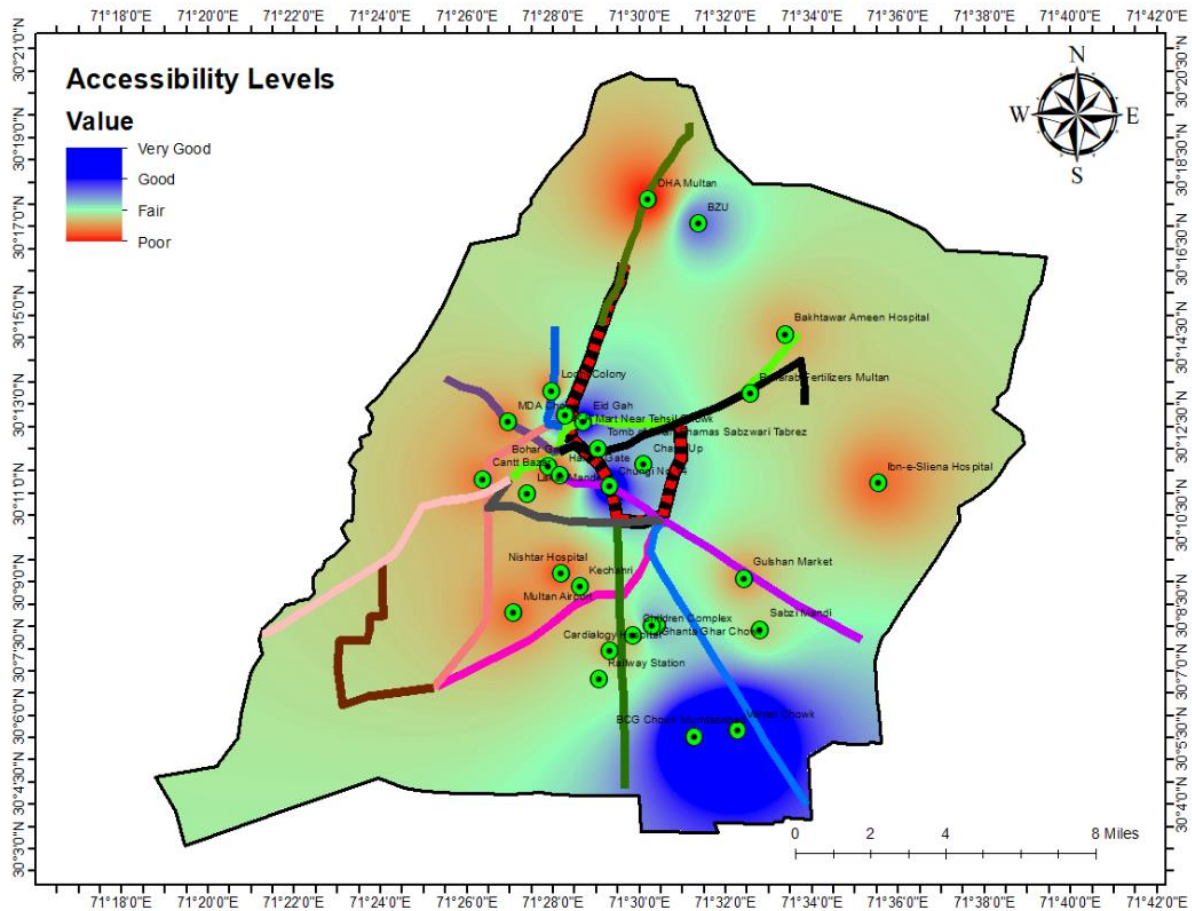


Figure 6: Finalized map (Accessibility levels of all POI using Accessibility Index Values).

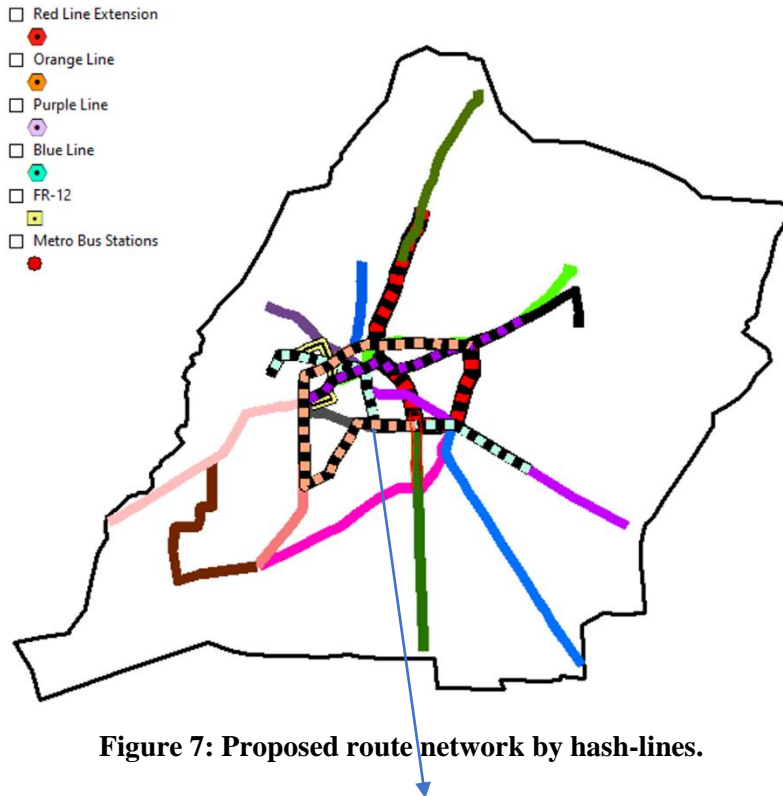


Figure 7: Proposed route network by hash-lines.

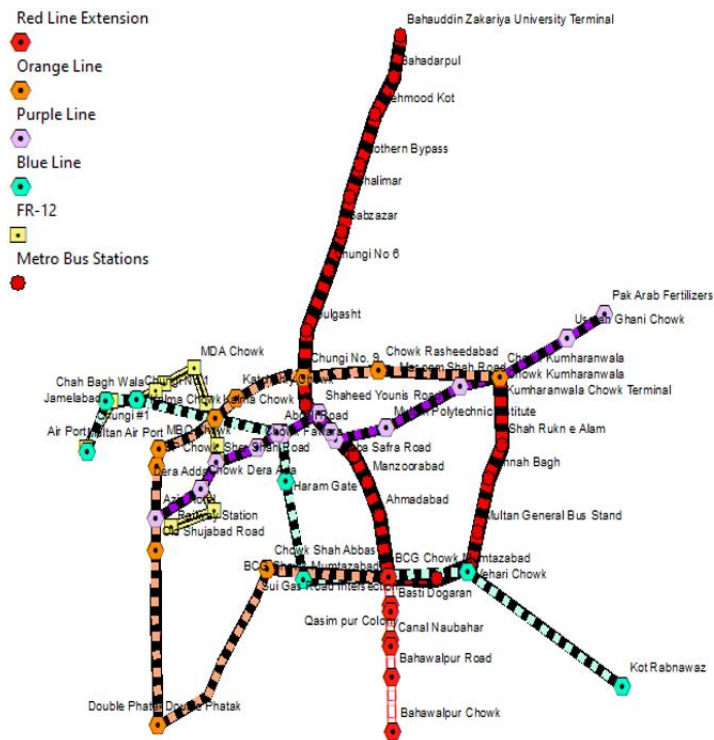


Figure 8: Proposed route network for improved accessibility.

5. Conclusions & Recommendations

The PTAL map can help improve the public transport system by identifying areas with poor accessibility, enabling decision-makers to prioritize investments. It also aids households in

making residential choices, particularly for low-income households. Real estate authorities can use PTAL and GIS maps to identify potential low-income housing schemes. Future extensions of the Metro Bus System and Veda Bus System Routes, such as the Red Line, Orange Line, Purple Line, Blue Line, and Veda Bus System, can be incorporated into PTAL calculations for better planning and implementation.

6. Acknowledgement

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