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GIS Network Analysis of Social Infrastructure Accessibility in Peshawar's Walled City

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ABSTRACT:
Social infrastructure is the backbone of a community that functions it, but in Pakistan public facilities are provided on a "population need" base, ignoring the "equally accessible for all" rule. In this study we evaluate the importance of Public transit, health, educational, Green spaces, worship places, law & order facilities, and their accessibility for an inclusive, Livable, Independent, healthy, and civilized neighbourhood and a GIS-based method of Network analysis (service area analysis) tool is used to analyze the accessibility within an 800 m walking distance (standard of 20-Minute city concept) into social infrastructure of Peshawar's walled city, including 6 types of public facilities like hospitals & BHUs, schools, Parks & open spaces, Police stations, Mosques, and the Bus Rapid Transit Peshawar's stations serving the settlement area. This tool quantifies the coverage area along the complex and irregular street network and identifies the facilities of maximum coverage by filling the walled city total area. We have health, Educational, and Mosques accessible within the 800 m walkable distance limit while the Parks and Police stations exceed the limit by 100 m and the BRT Peshawar station has a 1400 m walkable distance leading by 600m to reach the other side of the city. This analysis motivates improvement in spatial planning and resource distribution, and two Mini-Public Transit Service routes are proposed for the accessible, walkable, and sustainable walled City of Peshawar. The study may provide Urban Planners and development authorities with a broad view of public facilities provisions and limitations within the heritage-rich settlement.

KEY WORDS:
Social Infrastructure, Public Transit, Urban Accessibility, GIS, Network Analysis, Walled City of Peshawar

Introduction

Social infrastructure acts as a development machine of a community in the modern world (The British Academy, 2023). Imagine an Urban settlement without a school, hospital, parks, police, accessibility & roads, and public transit system; how will it survive but with social infrastructure, which plays a vital role in enhancing life quality, optimizing security and safety, promoting inclusivity and diversity (Latham, 2022), boasts wellbeing and functioning a community (Iurchenko, 2022), encourages affordability, crimes rate taming (Hutcheon, 2022), land values elevation, and social and economic aspects development of a community (Sabir, 2020).

The rapid urbanization and population rise lead to the mix-use development that requires proximity of public facilities and provision of amenities at walking distance for accessibility, better health (Tedja et al., 2023), literacy, delivery of grassroots support, diminish of inequality, societal advancement, inclusive urban spaces that demand regular resources provision commitment for sustainable development (Grum & Grum, 2020). However, different

localities have distinct accessibility, availability, and cost ratios to the infrastructure. The most preferred distance standard is the 20-minute city walkability standard, which requires 800 meters of distance coverage in 10 minutes (Gunn, 2017).

The best tool to analyze accessibility, urban planning, Tourism, and resource distribution is the map-based network analysis (Yuan, 2022). Also helps in the assessment of Green and blue infrastructure in balance with respect to population pressure (Wolff, 2021), and Road network optimization for tourism (Lepetiuk, 2023). Collaboration with artificial intelligence algorithms, such as ANFIS and ANN methods helps determine the factors related to urban network accessibility (Sahitya, 2021), and Health care for rural and sub-urban areas, GIS is a tool to analyze the opportunities and barriers in accessibility assuming topography and infrastructure limitations (Verma & Dash, 2020).

The research aim is to assess the existing social infrastructure and accessibility within walking distance of Peshawar's walled City. The study evaluates social infrastructure availability, determines the unserved area by Arc GIS Network Analysis tool by walkability standards, and proposes new facilities to fill the gap in the City. The structure of this paper follows Section 2 for a review of the study and case studies, section 3 outlines the study methodology approach, study area and its issues, the survey, data, and the tool used for analysis, section 4 evaluates the current situation, analysis and proposes facilities for solving the accessibility problem within the city.

Literature Review

The physical components that foster public interaction and assembling social capital are the public facilities known as social infrastructure (Strashnova, 2022). It contains initiatives and infrastructure necessary for the function of a community (Aldrich, 2023), including transport system, Health, Education, Law and Order, and Recreation or Public Spaces, including worship places (José Álvarez-García et al., 2023), to confirm that the community has a robust external effect and high living standard (Greed, 2022).

In urban planning, it is almost impossible to neglect the value of social infrastructure, the lack of which has a severe impact on a community's life quality, health condition, literacy rate, safety & security, and the general welfare of people (Aliona, 2023), that stimulate cooperation, interaction, and civic engagement among the members of society (Frolova et al., 2016), but the different regions and urban localities or even somewhere among the neighbourhoods within the same locality have a distinct level of social infrastructure availability ratio and accessibility that showing the social inequality, especially among the lower income group (Hasan et al., 2017).

The provision of critical social Infrastructure at the necessary distance and scale to accommodate the population and its density through spatial planning of the city centre is required to support the development of new communities or suburbs, resulting in sustainable development and communities (Alshawabkeh et al., 2022). Diverse and accessible cities link the global municipal and regional movement's agenda to that of fellow neighbourhoods (UCLG, 2019). The accessibility of the city's public Infrastructure determines people's living conditions, and technology promotes new opportunities for a rising number of disabled and aged population (Petríková, 2020).

Accessibility to facilities is an integral part of urban development, and the GIS-based assessment approach is used for the accessibility of social infrastructure facilities, consisting of a deep evaluation method for the buffer of Social Infrastructure and identification of unserved settlements (Dong et al., 2024). The one method is the Accessibility Index (AI), which is defined as "A population-weighted average travel time" (Deliry & Uygucgil, 2023), and the second method is the GIS Network Analysis approach efficiently examines the spatial arrangement of Infrastructure, which calculates the coverage flow radius distribution of multiple services and recommends the new facilities' coordinates (Khahro et al., 2023). In contrast, the simple method of buffering is used to evaluate the coverage of facilities to analyze accessibility (Frolova et al., 2016).

Urban Network Analysis and Kernel density spatial analysis are practiced in Chinghai County according to a study evaluating public service facilities in adjacent localities, the results exposed that there is a critical spatial disparity between facilities and residential areas, causing an overlap in construction and insufficient facilities distribution in some localities (Zheng & Zhao, 2023). Another case study in Jinan City, China, shows that an updated 2SFCA approach is used to assess the accessibility to various social Infrastructures and its effect on housing affordability. The accessibility of urban facilities and Infrastructure determines the living conditions of the residents (Yang et al., 2022)Research in Namdong-gu, Incheon Metropolitan City, South Korea, has used a simple approach to assess the accessibility to social Infrastructure and identify the unserved settlements. Libraries, Schools, Parks, Health, kindergartens, and sports facilities were all included in the research (Yhee, 2021).

In summary, social Infrastructure refers to the physical components of a community that enhance personal interaction and the development of social capital. It provides health, education, law and enforcement, and transportation services. Accessibility is crucial for urban planning, and GIS is the best tool to assess and analyze the coverage of facilities and identify the remaining unserved settlements. This infrastructure improves living conditions, promotes equality, and eliminates spatial disparity and resource distribution problems in urban areas.

Materials and Method

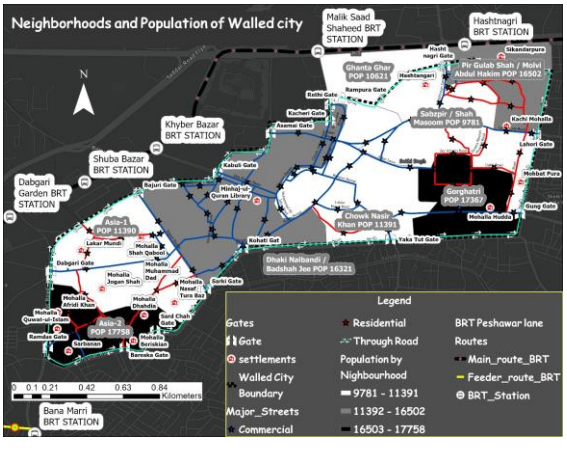
A mixed-methods approach is used in this study, to combine quantitative and qualitative data collection and analysis. The research design is descriptive and exploratory. At first, a base map is created from online map sources using GIS (Figure 2). A comprehensive field survey is conducted using the same base map, and many types of data are achieved, like main mobility street network segments'' widths, streets' infrastructure composition, and mid-lane traffic count. The data is analyzed, and a new, enhanced, comprehensive model of street infrastructure components, which should accommodate sustainable transport modes, is recommended.

Study Area

The Study area is the walled City of Peshawar, An Ancient walled Settlement with valuable heritage (Heritage Foundation of Pakistan, n.d.), Presenting distinctive Social, Economic, and Spatial structures that are Walkable, featuring congested thin streets, making it seem difficult for modern infrastructure Development and Restructuring (Jan, 2010). The City has covered by eight neighbourhoods (Figure 1) surrounded by a wall, including Sabzpir / Shah Masoom, Ghanta Ghar, Chowk Nasir Khan, Dhaki Nalbandi / Badshah Jee, Pir Gulab Shah / Molvi Abdul Hakim, Gorghatri, Asia-1 and Asia-2 (Local Government, Elections & Rural Development Department, n.d.), and 16 historical entry gates prominent of which are Kabuli Gate, Lahori Gate, and Kohati Gate and many more and are served by "Peshawar Bus Rapid Transit System" at 6 locations around the City on the North and West sides.

Figure 1

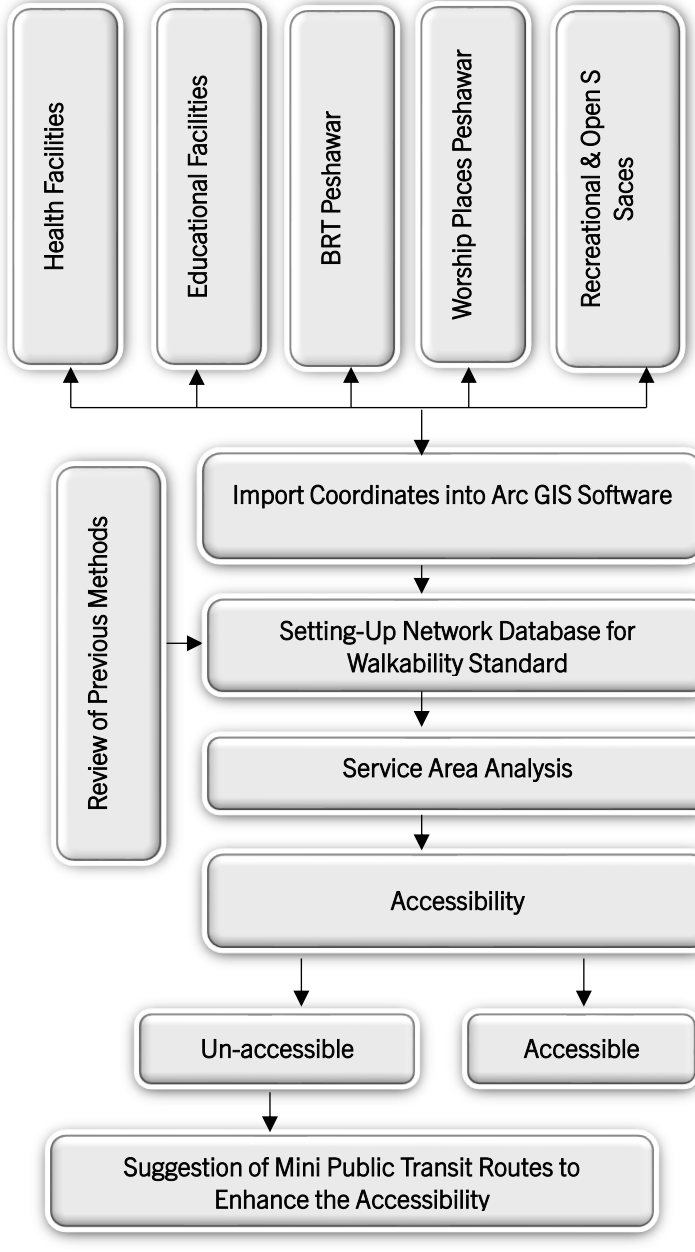
Neighborhood Boundaries & its Population in Peshawar Walled City



According to the 2017 Census of Pakistan, the City has a massive population of about 0.11 Million in an area of nearly 2 km2, making it a dense populated with mixed land use patterns and forms, making it a centre for Commercial activities having small and medium Enterprises (CDPR, 2019). Inadequate delivery of public services, especially the power supply, building regulations implementation, and the open drain sewerage system, are causing problems during the rainy season (Malik et al., 2021). The city is the CBD of Peshawar, and attracting more visitors to the compact commercial settlements causes a hap-hazard situation within the central mobility streets (Figure 1) (categorized into residential and commercial land use), the pedestrian flow shifts from footpaths to the roadway due to the encroachment by shop owners and the irregular markings. The social infrastructure facilities are quite tough but the main problem is acquiring suitable land for those facilities as the whole area is compactly built and the owners don't want to sell their valuable properties, which makes it hard for the government to populate the facilities on locations which is equally accessible for all. So here we are observing that either the facilities are accessible or need some improvement or addition.

Figure 2

Flow Chart of Methodology



Data

A field survey of Schools (Male & Female), Health (Private and Municipal) and Recreational, Open spaces facilities, Public Transport Stations (BRT Peshawar), Police stations & Judicial Complex, and worship places including Mosques, Church, Imam Bargah, Shrine, Gurdwara, and Temple is conducted, The handheld GPS device is used to collect the coordinates which are later imported to ESRI Arc GIS software, and the "Service area" feature in the Network Analysis tool is used for each facility individually to analyze the availability and accessibility within the walled city boundary. The gaps are identified, and recommendations are given at the end.

GIS "Network Analysis" Tool

The Network analysis tool in ESRI Arc Map is a powerful tool that allows users to analyze complex street network problems (ESRI, n.d.), provide solutions, and recommend Better locations for your facilities and Business using the accessibility phenomenon, including tools like Route finding, service area, Origin-Destination cost matrix, Vehicle route problem, and location-allocation (aArcGIS Desktop, n.d.). It uses DSA Dijkstra's Algorithm" to find the shortest path from one vertex to all other vertices (ArcGIS Desktop, n.d. & W3 School, n.d.). The tool uses a digitized street network to make a "Network Dataset" and sets analysis attributes like travel mode, speed, duration, elevated layers, and movement/driving behaviour (Das et al., 2019). When the environment is set out, the facilities are imported as a reference, the service area is analyzed, or other tasks are performed ([b]ArcGIS Desktop, n.d.).

Results and Discussion

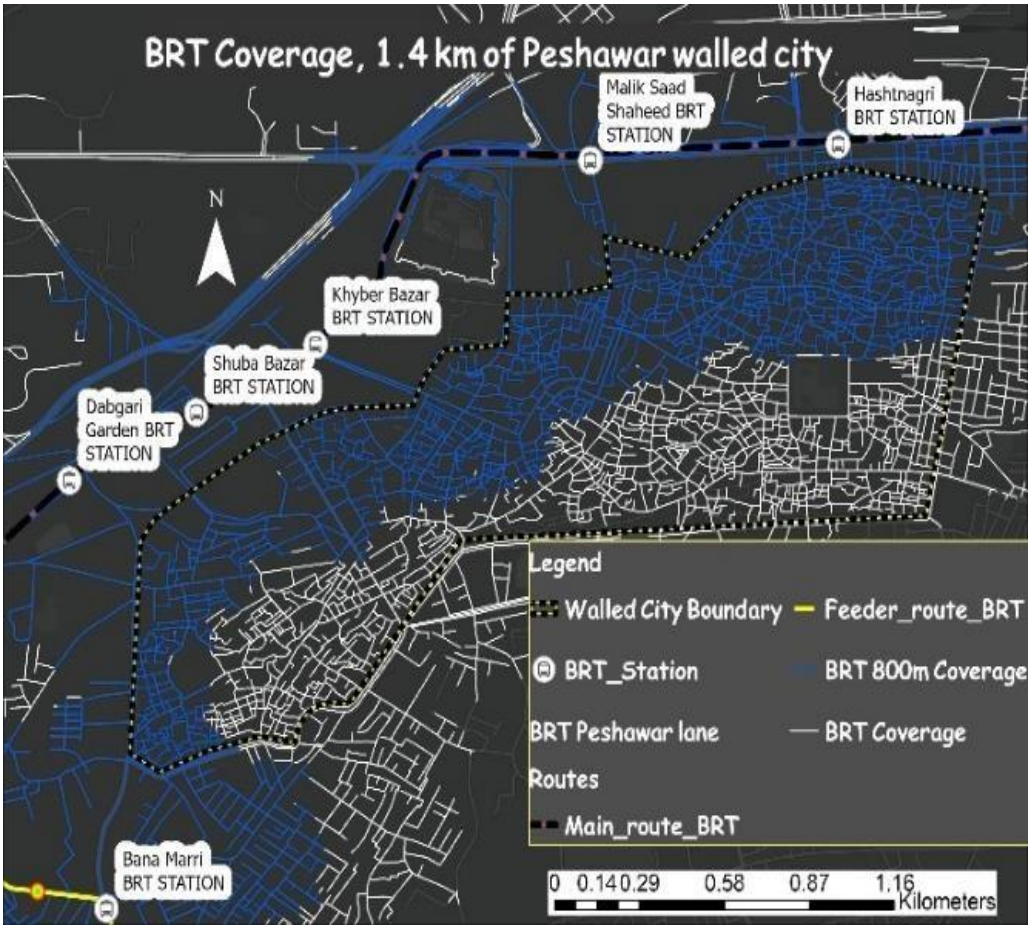
A detailed field survey is conducted in January 2024, and the facility's locations and coordinates will be collected using a GPS device. There are Six types of Public facilities are assessed including Public Transport, Health, Education, Open Spaces, Law & Order, and Religious Places. The Network analysis tool is used in Arc GIS pro software, with a walking distance strategy of covering 800 meters in 10 minutes. A standard for a walkable city distance, e.g., a 20-minute Bazar, Khyber Bazar, Malik Saad Shaheed, and Hashtnagri stations and a feeder route station at Bana Marri, Kohat Road (ADB, 2017). The network analysis output of BRT Peshawar (Figure 3) for 800m covering half of the area and 1.4 km of maximum walking distance is required to reach the other side of the walled City.

The capital city, Peshawar, has a modern Bus Rapid Transit System, the Trans Peshawar, also known as "Zu-Peshawar," operationalized in 2020 as the fourth BRT system in Pakistan (CDIA, n.d.). It has an East-West dedicated corridor of about 32 stations for rapid and efficient travel (Witte, 2019). A network of feeder routes makes the BRT a comprehensive system to serve most of the area off-corridor urban localities (PK BUSES, n.d.), including Hayatabad, Charsadda Road, Kohat Road, and under-suggestion Nasir Bagh Road (to serve DHA Peshawar and Regi Lalma Township).

In the city Seventy percent of the Peshawar urban area is served, with a 10-time increase in female ridership, 265000 daily passengers with 80-95% user satisfaction, and 27 km of corridor with 59 km of connecting routes, making this BRT a Golden category (ITDP et al, 2022). The effort is a collaboration between the government and the Asian Development Bank to improve urban mobility and flash the economic growth in the province's capital (WRI Ross Centre, 2022). Five consecutive BRT stations serve the walled City of Peshawar on dedicated corridors, including Dabgari Garden, Shoba Bazar, Khyber Bazar, Malik Saad Shaheed, and Hashtnagri stations and a feeder route station at Bana Marri, Kohat Road (ADB, 2017). The network analysis output of BRT Peshawar (Figure 3) for 800m covering half of the area and 1.4 km of maximum walking distance is required to reach the other side of the walled City.

Figure 3

BRT Peshawar "Service area" Analysis of Walled City



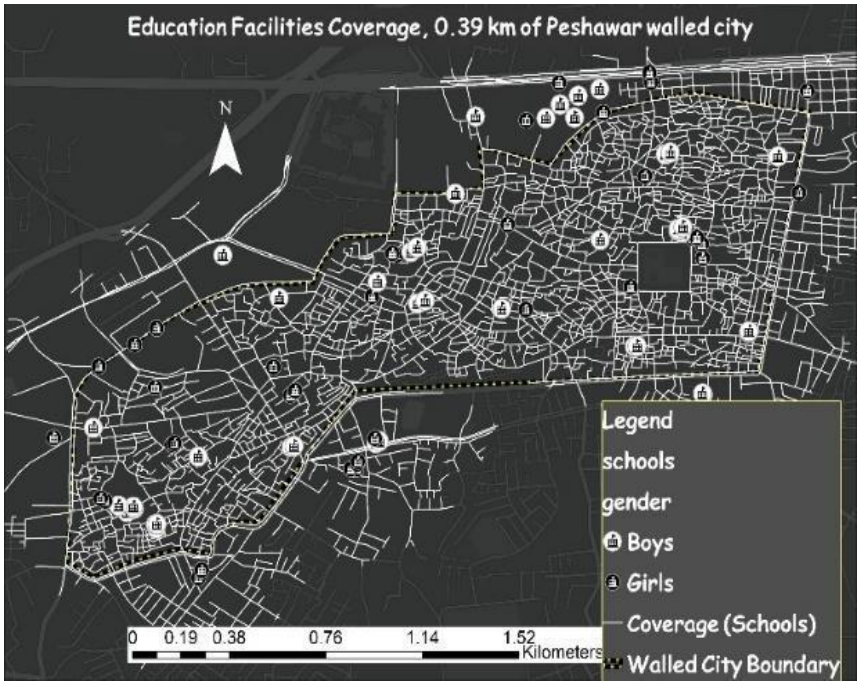
According to The Government of Khyber Pakhtunkhwa, n.d., the province has the third largest literary rate in Pakistan, making it 53% of its Province's population (The Government of Khyber Pakhtunkhwa, n.d.). Literacy is boosted by the popping up of educational institutions, comprising government Schools, Colleges, and Universities, and allowing the private sector partnership in the academic establishment and madrasa, which are traditional Islamic religious educational institutes. These developments are helping to increase the literacy rate among the diverse population 9 IPRI, 2015).

There are 82 government schools (Figure 4), of which 45 are for boys, and the rest are reserved for girls and serve up to Inter and higher education. The network analysis "service area" tool detected that each maximum distance to an educational facility needs only 390m of walkability, if the main streets are restructured for safe and efficient sustainable transport options, that will enhance the street's safety and comfort for children.

The walled City of Peshawar is a rich place with Health facilities, especially along the Kohat Road on the west side of the settlement. The medical requirements of the residents and the whole province at a certain level are fulfilled at this site, where hundreds of diverse medical specialists are equipped with modern equipment. The prominent one is the "Lady Reading Hospital," which can serve 5500 outpatients daily. According to 2018 data, the emergency and accidents department covers about 2500 to 3000 casualty victims daily 9 Wikipedia Contributors, n.d.). Despite the large number of facilities, there is a long gap between facilities at the hub of the walled City. According to Network Analysis, the health facilities are available at a proximity of about 760m from each (Figure 5), which is reasonably accessible according to the standard of 800m.

Figure 4

Educational Buildings "Service area analysis" of Walled City



It is a Business hub built of structures, including homes, shops, offices, and small industrial buildings. There is a little area of space for Greenery and open spaces. Despite the area having a dedicated Garden like "Dabgari Garden" Gorekhatri, a historical site with a small garden, Chowk Yadgar has a small amount of Greenery and a residential-type garden near the south wall. It's near Jinnah Park on the Northwest side, Shaikh Abad Park on the East, and Garden of Syed on the west side of the settlement. The proximity analysis shows that each facility could cover a maximum of 1km of walkable distance from each (Figure 6).

Figure 5

Health Facilities Service area analysis of the Walled City

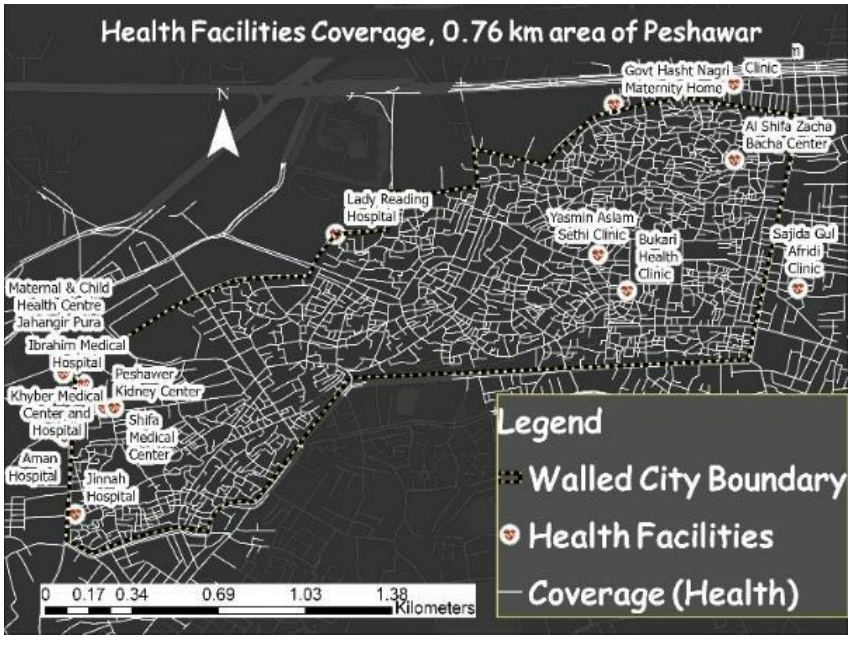
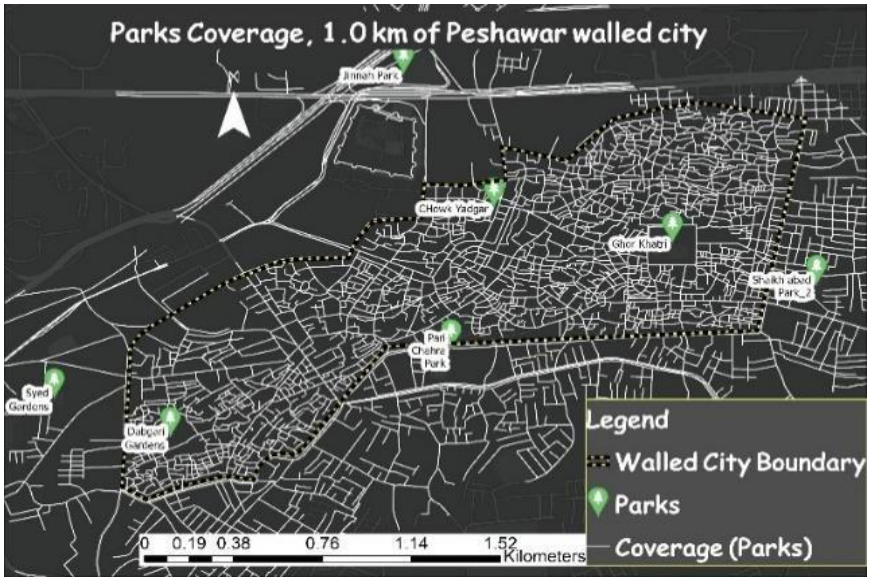


Figure 6

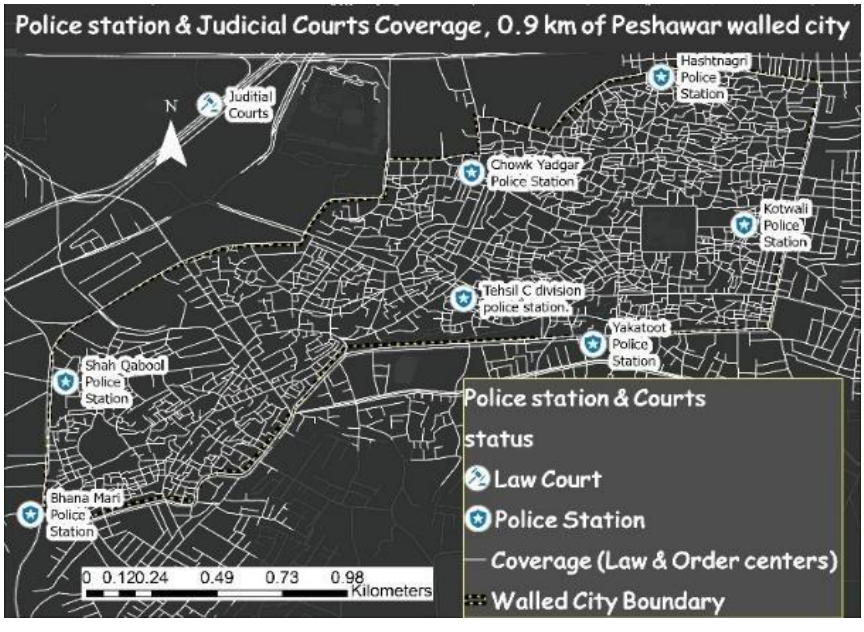
Parks & Open Space "Service area" Analysis of the Peshawar Walled City



For law and Order maintenance in the City, there are seven police stations built at a suitable distance. Some are just small security posts, and some are active Police stations, which act as neighbourhood hubs where people may Report crimes & injustice, get help, and access the court system. The accessibility analysis confirms that the police stations are available at a walking distance of 900m (Figure 7), much longer than is needed. The judicial courts are located some distance from the walled City, including The High Court, The Supreme Court, and The secretariat.

Figure 7

Police Stations' "Service area" Analysis of the Walled City of Peshawar

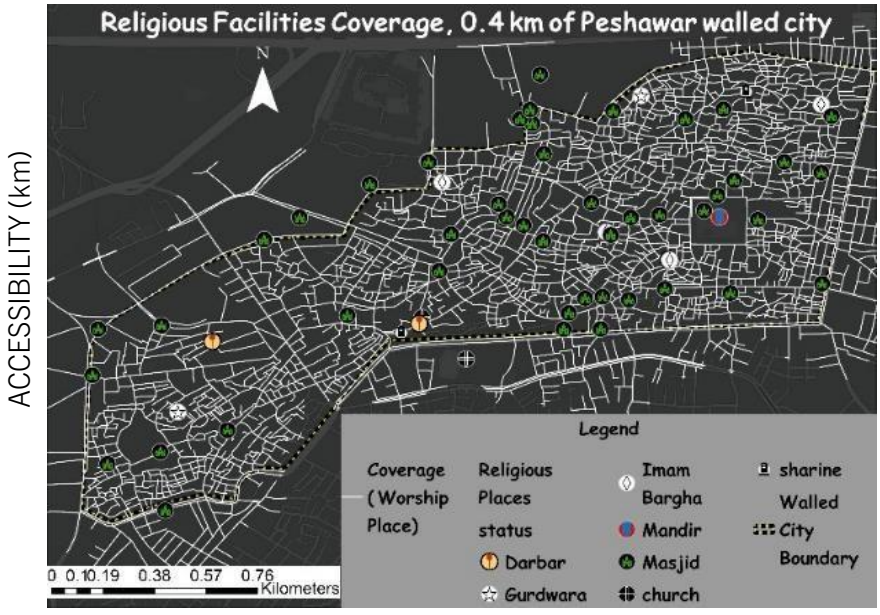


The City is a historical place and has served diverse communities. There are four types of worship places, including Muslims, Christians, Hindus, and Suk. The central community is Muslims, so the significant number of worship places are the most time usable places, The Mosques. The other religious places are visited once a week, so there is no need for proper availability at short distances. A total of sixty- eight Religious facilities are found, with two Churches, three Darbar, four Imam Bargha, two Gurdwara, a Hindu Temple, three Shrines, and forty-eight Mosques

in the area. The Mosques are available within under 400m circles (Figure 8) of maximum walkable distance, which is quite comfortable and accessible according to the walkable city proximity standard.

Figure 8

Worship Places Service area Analysis of the Walled City

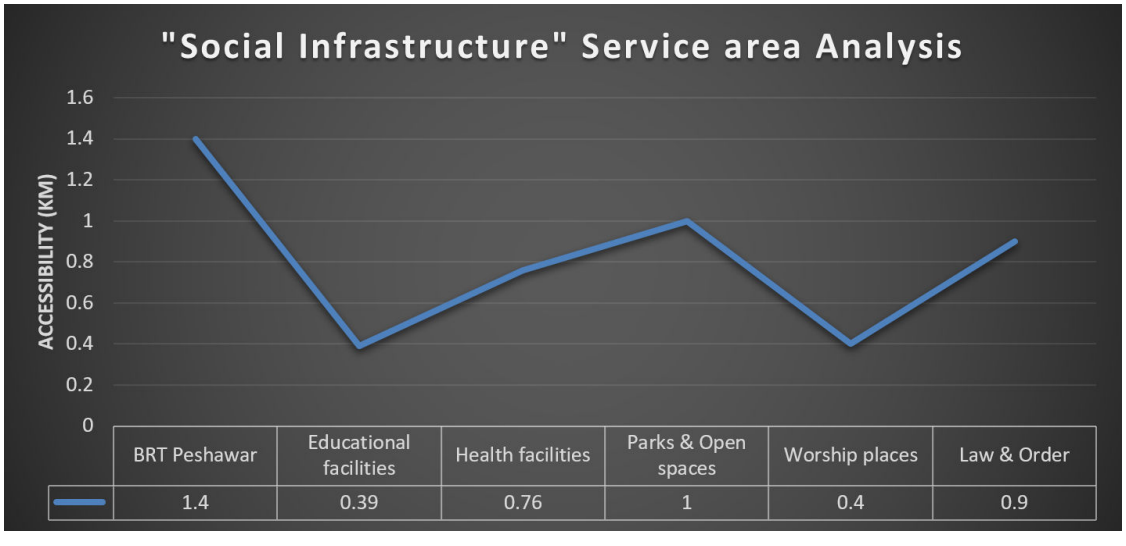


ACCESSIBILITY (km)

Analysis

Figure 9

Social Infrastructure" Service area Analysis



Analysis of the Social Infrastructure of Peshawar walled city confirms that we have six types of public facilities, three of which are accessible, and the rest are beyond the 800m limit for the walkability of Normal human beings. The BRT Peshawar stations cover the City on the Northeast side but require 1.4 km of walking (Figure 9) to the other side of the town, 600 m longer than needed. Law & Order facilities are at suitable locations, just a 100m distance to access. Parks & Open spaces are limited and located beyond the accessibility criteria, needing 200m extra walk to access another side of the City.

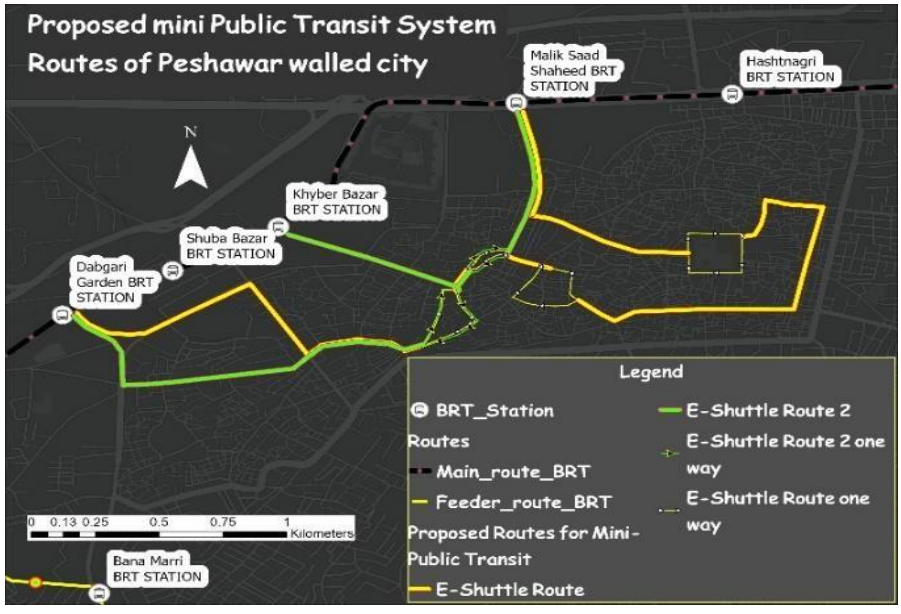
The accessible facilities are educational institutions that are abundant and accessible within 390m, and the Health facilities are accessible at 730m of walkability. However, there is a considerable gap in the central location

of the City, and mosques are squatted at a distance of about 400m walkable distance. To optimize urban functionality and livability, a comprehensive mobility plan that includes pedestrian pathways and cycling lanes integrated with public transit is essential.

Mini Public Transit Routes

Figure 10

Proposed Routes for Mini-Public Transit System within Peshawar Walled City



The major problem identified is the accessibility to public transit, which rests behind the walking standard of more than double the distance needed to approach BRT Peshawar Stations from some locations. To overcome this problem, we have identified two routes for a mini Public transit system (Figure 10) within the Peshawar walled city major street network to improve accessibility and mobility in safe, Affordable, comfortable, and Inclusive for all ages within the 100m of walkability, residents and visitors can access public transit from anywhere in the walled City.
The routes are connected to the BRT Peshawar system at three stations, given as,

- E-Shuttle Route
- E-Shuttle Route 2

The "E-Shuttle Route" is the longest and covers residential and all heritage sites and Commercial streets. The route is tapered in a single direction at two locations because of the existing setting of these streets connected to Dabgari Garden BRT Station and Malik Saad Shaheed BRT Station. The second, "E-Shuttle Service 2," is the shortest, covers all commercial streets, and meets the BRT Peshawar at three stations.

The Public Transport Service needs further study of the selected street network, including the width of each segment, The width of the Current carriageway and number of Lanes, direction, and, importantly, the level of service, which should be found by conducting the Traffic count survey of each lane segment separately, and then analyze whether the level of service is moderate for insertion of Mini public transit vehicles along the current traffic or replace some irrelevant mode like Rickshaw or Taxi which is abundant there and are expensive mode of transport, not affordable by poor residents.

Conclusion

The role of Social Infrastructure in our daily life is vital as if we have access to public facilities under a 10-minute origin-destination walk to achieve security, safety, affordability, Beauty, Health, entertainment, meditation, literacy, and movability. The Walled City of Peshawar has all those facilities in bulk, and in this study, we have assessed using

the Network Analysis tool of ESRI Arc GIS pro software for a walking distance of 800m. The Health, Educational, and worship places come under the accessibility circle, whereas the BRT Peshawar, Police stations, Parks, and open spaces exceed this limit. The need to improve accessibility provides a Mini Public Transit System routes carefully observed within the CBD are proposed as we have operational at some distance in Peshawar cantonment.

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