A GIS-Based Study on the 20-Minute City Concept and Accessibility: A Case Study of Ulaanbaatar City

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Abstract: *In recent years, urban planning has increasingly focused on enhancing residents' quality of life by improving accessibility, sustainability, and reducing transportation needs. This study investigates the feasibility of implementing the 20-minute city concept in Ulaanbaatar, where residents should access essential services within a 20-minute walk. Using QGIS and ArcGIS Pro software, we created heatmaps and conducted service area analyses based on the spatial distribution of schools, healthcare centers, green spaces, and commercial services across the city's residential areas. Findings reveal that central districts of Ulaanbaatar have good accessibility to essential services, while peripheral areas face significant service gaps. The study highlights the need to strengthen infrastructure and expand services in suburban districts to promote equitable urban development. By addressing accessibility disparities, Ulaanbaatar can better implement the 20-minute city concept and improve urban living standards. The research demonstrates the vital role of geographic information systems in urban spatial planning and offers recommendations for future city planning initiatives to achieve a more sustainable and inclusive urban environment.*

Keywords: *Geo-environment, sustainability, service area analysis*

Introduction

Urban planning today faces growing challenges in enhancing residents' quality of life, ensuring equitable accessibility, reducing dependence on private vehicles, and promoting environmental sustainability. One emerging approach that addresses these issues is the *15-minute/20-minute city* concept, which proposes that residents should be able to meet most of their daily needs—such as education, healthcare, shopping, and leisure—within a short walking or cycling distance of their homes (Capasso & Da Silva, 2019; McNeil, 2011; Moreno et al., 2021). Globally, this framework has gained increasing recognition as a pathway to encourage active mobility, improve public health, and support sustainable urban lifestyles.

In Mongolia, the *Ulaanbaatar City Master Plan 2040* incorporates the principles of resilience, compact growth, accessibility, and sustainability. Within this plan, the "20-minute city" reform is emphasized as a planning framework for ensuring that citizens can access basic public and social services within a 20-minute walk from their homes (Tuvshinjargal., 2024). However, despite this vision, the urban form of Ulaanbaatar presents unique challenges. A large proportion of the city's population resides in *ger districts*, which lack adequate infrastructure,

public services, and planned street networks. These conditions exacerbate issues of accessibility, inequality, and environmental stress (Battsuuri & Batbayar, 2020; Hamiduddin et al., 2021).

Given Ulaanbaatar's vast urban territory and its uneven population density, assessing the feasibility of applying the 20-minute city concept is of particular importance. Modern spatial technologies, such as Geographic Information Systems (GIS) and multi-criteria decision analysis, offer valuable tools for examining accessibility, identifying service gaps, and supporting evidence-based urban planning (Purevtseren & Sukhbaatar, 2017).

Ulaanbaatar, the capital and the principal economic, cultural, and educational hub of Mongolia, has experienced rapid population growth and urban expansion over the past decades (Parliament of Mongolia., 2023). This demographic concentration, driven by rural-to-urban migration and economic centralization, has been a key force shaping the city's development. However, such rapid urbanization has also generated a series of challenges, including severe traffic congestion, increasing pressure on urban infrastructure, and unequal access to public and social services. Addressing these issues requires comprehensive urban planning, the modernization of public transportation systems, effective housing development policies, and enhanced accessibility to essential social services, all of which are necessary to ensure sustainable urban growth (Asian Development Bank., (2022); World Bank., 2020).

This study contributes to this discourse by applying GIS-based spatial analysis to evaluate accessibility patterns in Ulaanbaatar and by discussing implications for achieving more sustainable and equitable urban development.

Literature Review

Accessibility and walkability have been widely studied as key components of sustainable urban development. Previous research highlights that compact urban form, efficient public transport, and well-connected pedestrian networks are critical for achieving equitable access to essential services (Siragusa et al., 2019; Cyr et al., 2022). The "15-minute city" model has been tested in various international contexts, demonstrating its potential to reduce car dependency, enhance social inclusion, and support healthier lifestyles (Smith & Hansen, 2021; Moreno et al., 2021).

In the context of Ulaanbaatar, several studies have examined accessibility and mobility issues. Unurbayar and Purev-Erdene (2021) analyzed pedestrian access around bus stops and public facilities in central districts, identifying barriers that hinder walkability. Similarly, Oyunbileg

(2024) conducted a GIS-based network analysis to assess the lack of accessibility to social services in ger districts, emphasizing inequalities between central and peripheral urban areas.

These findings illustrate that Ulaanbaatar's urban structure poses significant challenges for equitable service provision. While international literature provides a strong foundation for understanding the 15- or 20-minute city concept, localized studies in Ulaanbaatar show persistent service gaps, particularly in peripheral districts. However, a comprehensive spatial analysis combining both heatmap and service area approaches has been limited. This research seeks to address that gap by systematically evaluating service accessibility across the entire residential area of Ulaanbaatar, thereby contributing both to the academic discourse and to practical urban policy.

Methodology

The methodological framework of this study was designed to integrate spatial analysis techniques to evaluate accessibility to essential urban services within a 20-minute walking distance in Ulaanbaatar. Both quantitative and spatial approaches were employed, relying on geospatial datasets and GIS-based analytical tools. The study primarily made use of two types of spatial data: the pedestrian road network and the locations of service facilities. Road network data were obtained from OpenStreetMap, Google Maps API, and the Ulaanbaatar Land Authority, ensuring that the modeled network reflected actual walking paths and road connectivity. Service facility data included educational institutions such as schools, kindergartens, and universities; healthcare facilities such as hospitals, clinics, and pharmacies; commercial centers including shops, markets, restaurants, and banks; as well as green and recreational spaces like parks and sports halls. In total, 6,675 service points were compiled, representing the full spectrum of daily services considered necessary for implementing the 20-minute city concept.

The analytical process consisted of two complementary stages. First, a heatmap analysis was conducted using Kernel Density Estimation (KDE) in QGIS. This technique allowed the visualization of service facility concentrations and spatial patterns of distribution across the city. The KDE was applied with a spatial resolution of 500 x 500 meters, and a kernel bandwidth of one kilometer was selected to approximate the influence zone of each facility. This step revealed areas of high service concentration as well as zones where services were sparse, thereby providing an overview of the spatial heterogeneity of accessibility.

$$f(x,y) = \frac{1}{nh^2}\sum_{i=1}^{n} K\left(\frac{x-xi}{h}, \frac{y-yi}{h}\right) \quad (1)$$

where f(x) is the estimated density at location x, n is the number of data points, h is the bandwidth controlling the smoothing parameter, and K represents the kernel function. In this study, a bandwidth of 1 km was applied, meaning that the influence of each facility extended over a one-kilometer radius.

Second, a service area analysis was performed in ArcGIS Pro using the network dataset of Ulaanbaatar. This analysis generated polygons representing areas that could be reached within a 20-minute walk from each service facility. By applying a shortest path algorithm that accounted for road type and connectivity, the service area analysis provided a more realistic estimation of pedestrian accessibility than Euclidean distance. The results of this stage highlighted specific districts where essential services were easily reachable on foot, as well as peripheral areas where accessibility was severely limited.

$$\text{Cost}\,(i,j) = \sum_{k=1}^{n} w_k \cdot d_k \quad (2)$$

where $\text{Cost}\,(i,j)$ *represents the cumulative travel cost from an origin (i)- to a destination (j), wk-is the weight assigned to the type of road segment, dk is the distance or travel time of segment dk , and n is the total number of segments along the path. This formulation ensured that differences in road type and connectivity were incorporated into the analysis, producing a realistic estimation of walking accessibility.*

To support the robustness of the analysis, mathematical formulations were employed to quantify accessibility. The KDE function was applied to calculate service density across the city, while the service area analysis was guided by a travel cost function that considered both distance and road type weights. Together, these two approaches provided complementary perspectives: the heatmap illustrated overall service distribution trends, whereas the service area analysis quantified actual accessibility within the temporal constraint of 20 minutes.

Finally, the outputs of both analyses were synthesized and mapped to facilitate interpretation. By comparing central and peripheral districts, the study was able to reveal significant inequalities in service provision. The methodological design therefore ensured that the analysis was comprehensive, integrating both density-based and network-based perspectives to produce a realistic assessment of accessibility in Ulaanbaatar.

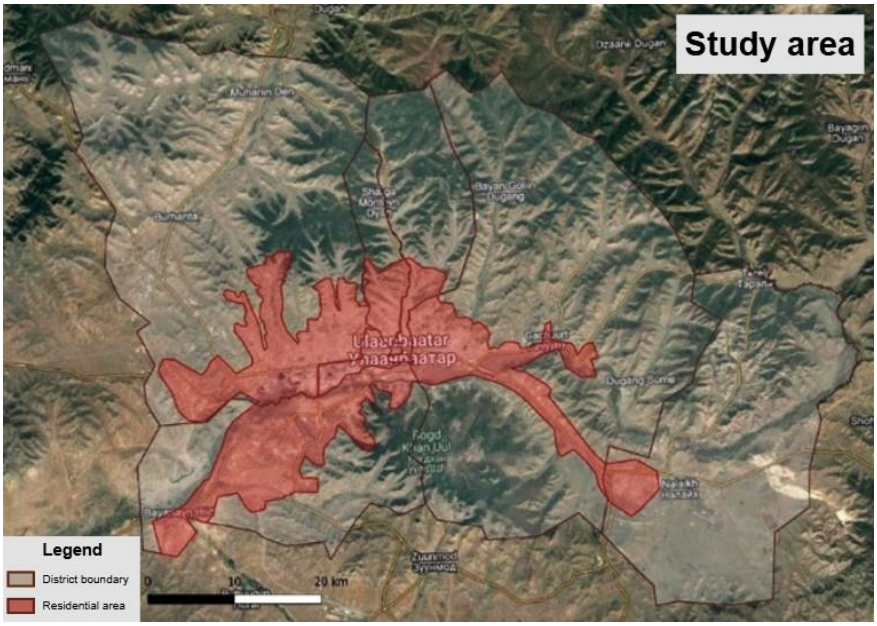

Figure 1: Study area

Results and Discussion

The analysis indicates that most service facilities, including kindergartens, schools, healthcare centers, entertainment venues, and government institutions, are highly concentrated in the central areas of Ulaanbaatar. In contrast, peripheral districts exhibit limited accessibility to essential services, particularly in the domains of education and healthcare. Government services are also centralized in the city core, creating difficulties for residents in peripheral districts to access these facilities. This highlights the necessity for policy interventions to decentralize services and improve accessibility in suburban areas.

The heatmaps generated in QGIS and the service area analysis performed in ArcGIS Pro effectively visualized the spatial disparities in service concentration and accessibility. When compared with previous studies (Oyunbileg, 2024; Unurbayar & Purev-Erdene, 2021), the results consistently demonstrate the persistent lack of essential services in ger districts, confirming that inequitable service distribution remains a critical challenge.

Figures 2 and 3 illustrate that while services in the city center are easily accessible within a 20-minute walking radius, accessibility sharply declines in the outer districts. Figure 4 further shows that areas with high service overlap, represented by dense green zones, align with the concept of the “20-minute city,” as they enable access to up to 18 categories of services. Conversely, accessibility decreases toward the peripheries, as represented by the color gradient shifting toward red.

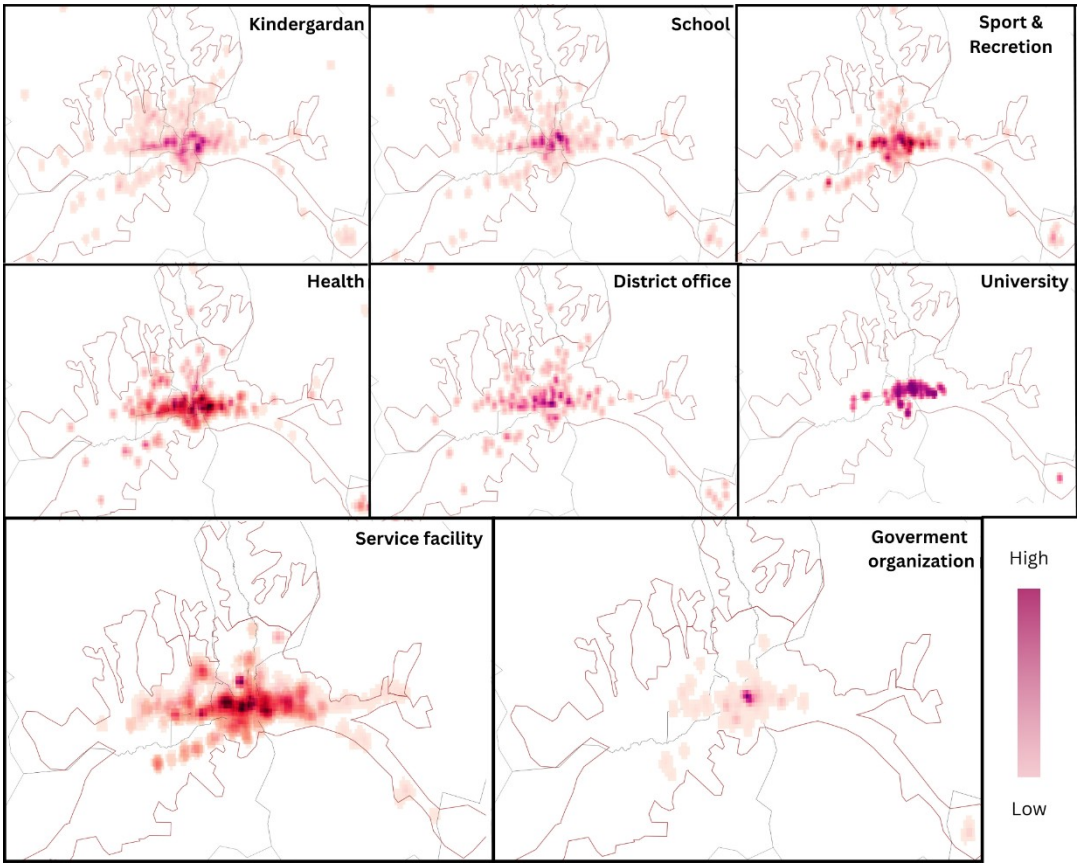

Figure 2 Accessibility of government and service facilities in Ulaanbaatar (by subcategories).

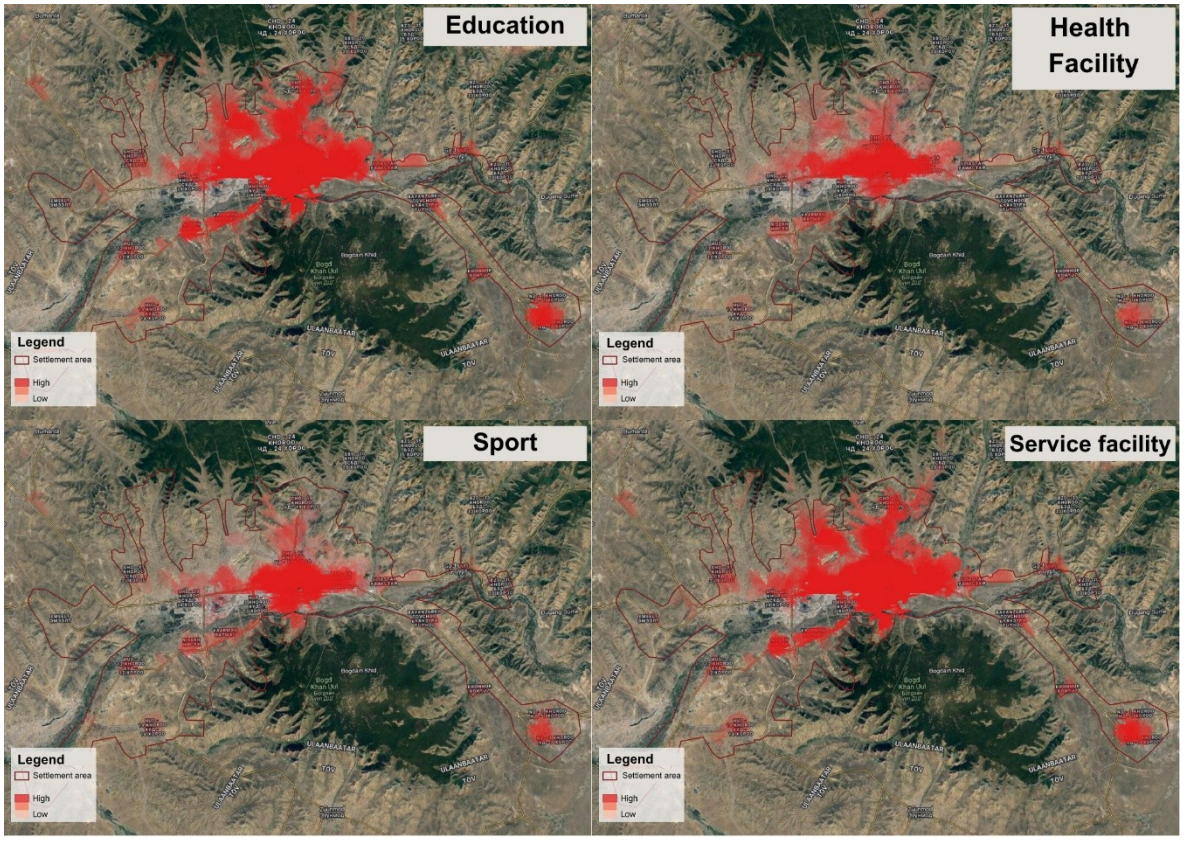

Figure 3 Twenty-minute accessibility map of Ulaanbaatar (by subcategories).

A comparative case analysis (Figures 5–6) reveals distinct spatial differences across selected locations. Zone A demonstrates high service concentration and aligns closely with the 20-minute city model. Zone B1 and Zone B2 have partial accessibility to certain services but remain limited compared to central areas. Zone C is marked by restricted accessibility, with residents facing significant challenges in reaching essential facilities. These results emphasize the need for targeted infrastructure development and service expansion in peripheral zones to improve residents' quality of life.

The findings suggest that while Ulaanbaatar's central areas are well positioned to support the 20-minute city concept, substantial gaps remain in peripheral and ger districts. Addressing these disparities requires policy measures such as establishing new educational, healthcare, and sports facilities, enhancing pedestrian infrastructure, improving public transport connectivity, and planning smaller service hubs in suburban districts. Strengthening these aspects will not only improve residents' living conditions but also promote spatial equity and contribute to sustainable urban development.

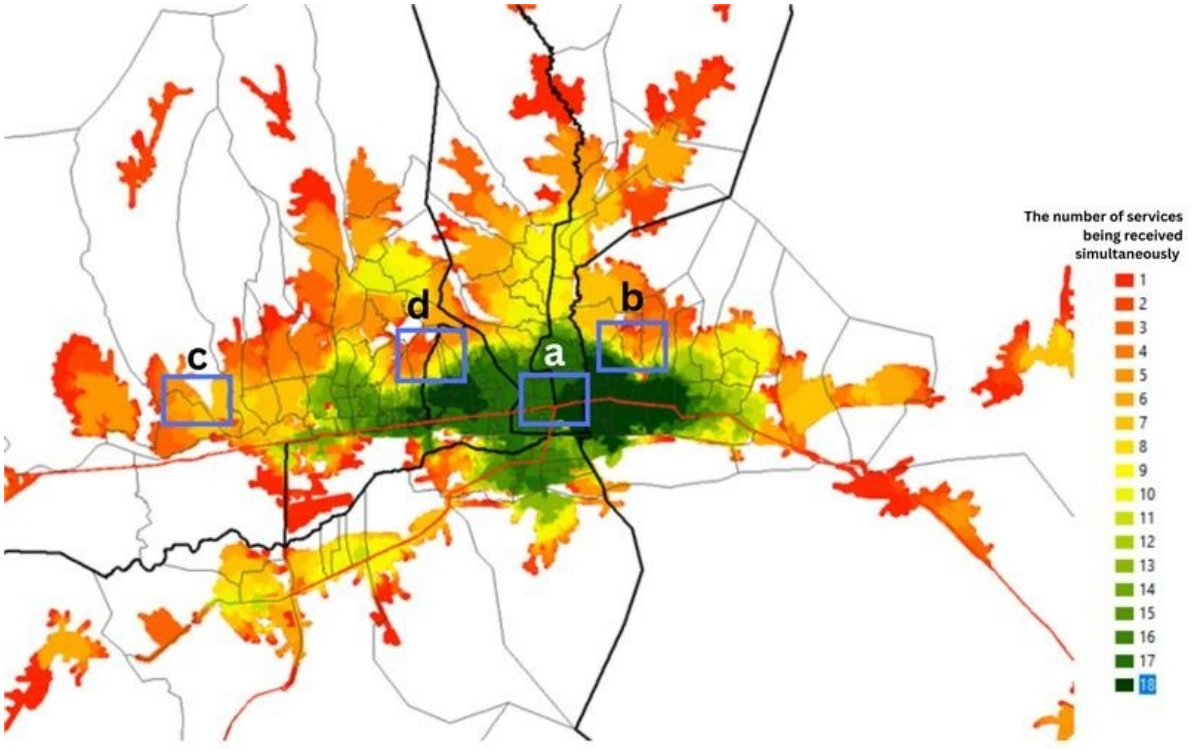

Figure 4: Twenty-minute accessibility map of Ulaanbaatar.

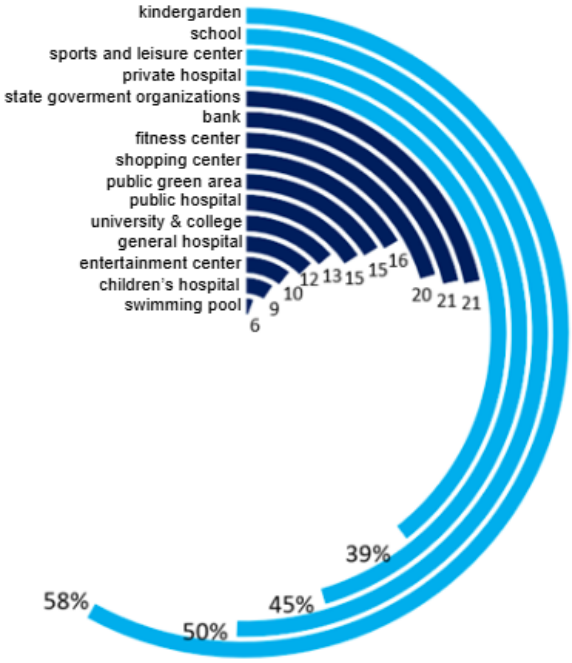

Figure 5 Graph 1 Proportion of areas within Ulaanbaatar's residential zones reachable by walking within 20 minutes.

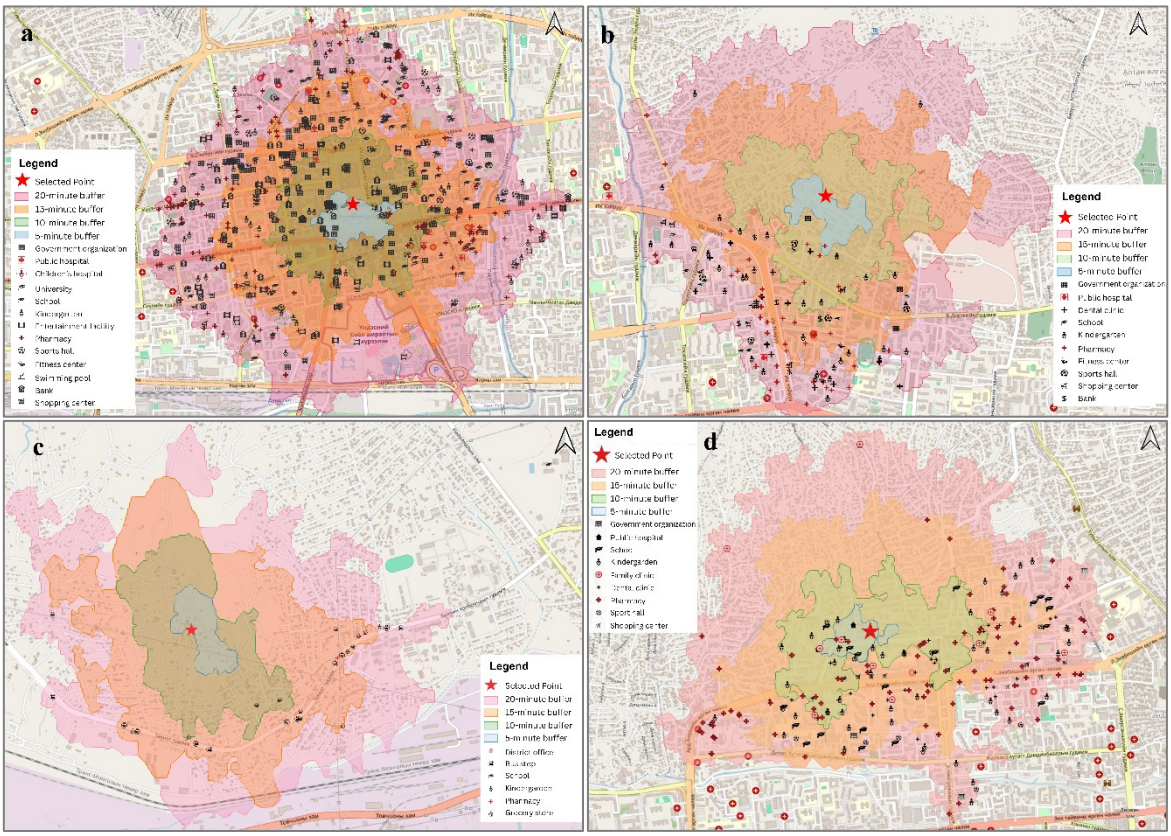

Figure 8. Areas reachable within 5, 10, 15, and 20 minutes from a specific point in the geo-environment: Zone A1, b. Zone B1, b. Zone B2, c. Zone C

Conclusion and Recommendation

This study evaluated the feasibility of implementing the 20-minute city concept in Ulaanbaatar using geographic information system (GIS) methods. The findings reveal significant spatial disparities in service accessibility between central and peripheral districts. While the city center demonstrates relatively good accessibility to education, healthcare, commercial services, and green spaces, peripheral and ger districts remain underserved, with lower service density and limited accessibility.

The heatmap and service area analyses provided clear evidence of these inequalities, aligning with earlier studies (Oyunbileg, 2024; Unurbayar & Purev-Erdene, 2021). The results highlight that Ulaanbaatar's urban structure, shaped by concentrated development in central areas, limits the potential for equitable implementation of the 20-minute city model across the entire metropolitan region.

To strengthen the realization of the 20-minute city in Ulaanbaatar, several policy measures are recommended:

1. **Expansion of services in peripheral districts** – Establish new educational, healthcare, and sports facilities to address service gaps.
2. **Improvement of pedestrian infrastructure** – Develop safe, inclusive, and continuous walking networks to facilitate active mobility.
3. **Enhancement of public transportation** – Increase connectivity between central and suburban areas to reduce accessibility disparities.
4. **Decentralized service hubs** – Plan and develop small-scale service centers in outer districts to reduce dependence on the urban core.
5. **Integration of green spaces** – Ensure equitable distribution of parks and recreational areas across all districts to support sustainable urban living.

By implementing these measures, Ulaanbaatar can reduce spatial inequalities, enhance residents' quality of life, and move toward a more sustainable, inclusive, and resilient urban future in line with the principles of the 20-minute city.

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