NATIONAL UNIVERSITY OF MONGOLIA
SCHOOL OF ART AND SCIENCES
DEPARTMENT OF GEOGRAPHY

Geographical Issues

Газарзүйн Асуудлууд

Volume 26 (02) *ISSN: 2312-8534* *2026*

Ulaanbaatar

Comparative Analysis of Pedestrian Sidewalk Standards in Ulaanbaatar, Mongolia

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Received: 2025.12.15
Revised: 2026.04.13
Accepted: 2026.04.15

Abstract

Walkability and pedestrian accessibility are central to sustainable urban development but remain particularly challenging in cold-climate cities, where thermal comfort and seasonal conditions strongly influence mobility patterns. In Ulaanbaatar, a rapidly urbanizing city with an extreme continental climate (mean annual temperature of −1.3°C), pedestrian infrastructure is constrained by vehicle-oriented street design and limited right-of-way allocation. Although Mongolia has adopted the national pedestrian planning standard UCS 0901B:2022, its spatial adequacy across different urban contexts has not been systematically evaluated. This study assesses pedestrian infrastructure across four representative street typologies—peri-urban (ger-area) redevelopment, commercial, modern residential, and institutional corridors—using comparative cross-sectional analysis combined with international benchmarking against nine global cities. The results identify pedestrian width as a key spatial determinant of functional pedestrian environments. Two critical thresholds, approximately 2.0 m and 2.5 m, are shown to govern the feasibility of buffer space and canopy-forming vegetation in cold-climate conditions. International comparisons indicate that pedestrian widths in Ulaanbaatar are approximately 40–60% narrower than typology-matched global references across all street categories. These findings highlight a systematic mismatch between current standards and functional spatial requirements. The study provides the first empirical evidence in Ulaanbaatar supporting the adoption of typology-specific pedestrian width targets and integrated green buffer requirements. It therefore recommends revising UCS 0901B:2022 to move beyond a single uniform minimum standard toward a more context-sensitive, performance-based framework for pedestrian planning in cold-climate cities.

Keywords: *Walkability; pedestrian infrastructure; cross-sectional analysis; green infrastructure; UCS 0901B:2022; international benchmarking*

Улаанбаатар хотын явган зорчигч замын стандартын харьцуулсан шинжилгээ

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Хүлээн авсан: 2025.12.15
Засварласан: 2026.04.13
Зөвшөөрөгдсөн: 2026.04.15

Хураангуй

Явган замын хүртээмж нь хотын тогтвортой хөгжлийн үндсэн бүрэлдэхүүн хэсэг боловч улирлын нөхцөл байдал нь замын хөдөлгөөний хэв маягт хүчтэй нөлөөлдөг хүйтэн уур амьсгалтай хотуудад хэрэгжүүлэхэд онцгой хүндрэлтэй байдаг. Олон жилийн дундаж агаарын температур нь −1.3°C хэмтэй байдаг Улаанбаатар хотод авто тээврийн төлөвлөлт, явган замын зай, талбайн хүрэлцээгүй байдал нь зорчиход ихээхэн хүндрэл үүсгэдэг. Монгол Улс явган замын UCS 0901B:2022 стандартыг баталсан ч энэ стандарт бодит байдал дээр Улаанбаатар хотын орчинд хэр сайн хэрэгжиж байгааг хангалттай судалж үнэлээгүй байдаг. Энэ судалгаагаар гэр хороолол, худалдаа үйлчилгээ төвлөрсөн бүс, шинэ орон сууц, оюутны гудамж гэсэн дөрвөн төрлийн орчинд явган хүний дэд бүтцийг судалж, Гадаадын 9 хоттой харьцуулсан шинжилгээ хийв. Энэхүү судалгаагаар нь Улаанбаатар хотод явган хүний замын өргөн 2.0 м болон 2.5 м гэсэн хоёр босго хэмжээг тодорхойлсон. Энэ нормоос доош болон дээш өргөнтэй замд ногоон зурвас болон сүүдэр үүсгэх модлог ургамал төлөвлөх боломж мэдэгдэхүйц өөрчлөгдөж байгааг тогтоосон. Олон улсын ижил төрлийн гудамжны ангиллуудтай харьцуулсан дүнгээр Улаанбаатар хотын явган хүний замын өргөн нь бүх дөрвөн ангилалд дэлхийн жишигтэй харьцуулахад ойролцоогоор 40–60 хувиар нарийн байв. Иймээс UCS 0901B:2022 стандартыг нэг ижил доод босго хэмжээнд тулгуурлах бус, гудамжны ангилал тус бүрт тохирсон явган хүний замын өргөний зорилтот хэмжээ болон ногоон зурвасын шаардлагыг тусган шинэчлэх шаардлагатайг энэхүү судалгааны үр дүн харуулж байв.

Түлхүүр үгс: *явган хүний зам; явган хүний дэд бүтэц; ногоон дэд бүтэц; UCS 0901B:2022; олон улсын жишиг үнэлгээ*

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Introduction

Walkability has become a central concept in contemporary urban planning because it links everyday mobility with public health, environmental sustainability, and social equity. Urban design significantly influences walking behavior, including factors such as safety, comfort, and accessibility (Alfonzo, 2005). Pedestrian-friendly environments support physical activity, reduce automobile dependence, and improve urban livability, especially for children, older adults, and people with disabilities (Giles-Corti et al., 2016; Ewing & Handy, 2009). Beyond physical accessibility, the quality of urban street environments also has measurable psychological effects on residents (Mandkhai, 2025), reinforcing the case for holistic pedestrian infrastructure design. For this reason, many cities and international organizations have developed pedestrian design standards and assessment frameworks to guide safer, more comfortable walking environments (NACTO, 2016; UN-Habitat, 2015; WHO, 2018).

However, walkability research and practice remain uneven across regions. Many widely used assessment approaches were developed in cities with mild climates, long-established infrastructure, and relatively stable street environments, most commonly in North America, Western Europe, and parts of East Asia (Arellana et al., 2020). These approaches often emphasize accessibility, connectivity, and land-use patterns, while giving less attention to environmental protection and seasonal performance. As a result, methods and standards derived from those contexts may not translate well to cities with extreme climates, where walking conditions depend heavily on microclimatic mitigation such as wind protection, shade, and surface durability. Studies in cold-climate Asian cities have shown that pedestrian infrastructure quality directly affects winter mobility and public health outcomes (Leather et al., 2011). In the Mongolian context, research on urban heat islands, air pollution, and ger-area redevelopment has grown substantially, but systematic evaluation of pedestrian space allocation remains limited (Soyol-Erdene et al., 2021; Choi & Enkhbat, 2020). Emerging Mongolian scholarship has also begun examining pedestrian accessibility for specific user groups including visually impaired people (Nomin-Erdene, 2024) and the psychological dimensions of urban street environments (Mandkhai, 2025). Studies on Ulaanbaatar's urban expansion have further documented the spatial dynamics of ger-area transformation (Choi & Enkhbat, 2020; Gombodorj et al., 2025) and the environmental health consequences of unplanned development (Soyol-Erdene et al., 2021; Sumiya et al., 2023; Nyam-Osor et al., 2024), yet typology-based spatial assessment across different street types remains largely absent.

Ulaanbaatar, the capital of Mongolia, represents a particularly challenging context for pedestrian mobility. The city experiences long, cold winters, frequent wind exposure, and large seasonal temperature variations, creating conditions where pedestrian comfort and safety are strongly influenced by street design and protective greenery. In cold and windy environments, canopy-forming trees and vegetated buffers can function as climate infrastructure, reducing wind chill, moderating thermal stress, and improving year-round walkability (Aghamolaei et al., 2023). Yet rapid urbanization and increasing motorization have encouraged vehicle-oriented street layouts, often producing narrow pedestrian corridors that limit the feasibility of functional green buffers (Leather et al., 2011).

To improve pedestrian infrastructure quality, Mongolia adopted the national pedestrian planning standard UCS 0901B:2022, which defines minimum pedestrian width and related design requirements. While this standard provides an important regulatory baseline, two practical questions remain insufficiently examined. First, the spatial characteristics of pedestrian infrastructure across Ulaanbaatar's dominant street typologies have not been systematically documented or compared against international practice, limiting the evidence base needed to inform future standard revisions (Gombodorj et al., 2025). Second, systematic evaluation across different urban typologies, such as institutional streets, commercial corridors, modern residential developments, and ger-area redevelopment zones, remains limited. In addition, there is little evidence-based comparison showing how Ulaanbaatar's typical pedestrian widths relate to international practice in comparable street types.

This study addresses these gaps through a comparative cross-sectional analysis of pedestrian infrastructure in Ulaanbaatar combined with international benchmarking. Four representative local street typologies are examined: ger-area redevelopment (Zuun Salaa Street), traditional commercial (L. Enebish Avenue), modern residential development (Vega City), and an institutional corridor (Sambuu Street), which serves as a local pilot case. These are benchmarked against pedestrian width allocations from nine international cities, including Beijing, London, and Brasilia, representing diverse planning traditions and climatic contexts. By comparing cross-sections across typologies, the study identifies spatial thresholds that determine whether green buffers and canopy vegetation are feasible within pedestrian right-of-way.

Accordingly, the objectives of this research are to: (1) review international pedestrian accessibility and street design standards and compare them with Mongolia's UCS 0901B:2022; (2) analyze cross-sectional street profiles to assess pedestrian width allocation and green infrastructure viability across Ulaanbaatar's dominant typologies; (3) benchmark Ulaanbaatar's pedestrian width against international examples to quantify relative infrastructure deficits; and (4) evaluate the relationship between pedestrian corridor width and the feasibility of canopy-forming vegetation in a cold-climate urban context. By integrating regulatory review, spatial measurement, and international comparison, this study aims to inform future revisions of pedestrian planning standards and contribute to the broader discussion of climate-resilient walkability in cold-climate cities.

Study Area

Ulaanbaatar, the capital city of Mongolia, serves as the primary geographical context for this research. The city is located within the intermontane basin of the Tuul River at an elevation of approximately 1,350 meters above sea level (Figure 1). It experiences a strongly continental, cold semi-arid climate characterized by long winters, frequent wind exposure, and substantial seasonal temperature variation (Dorjgotov, 2009; Sumiya et al., 2023; Nyam-Osor et al., 2024). The mean annual air temperature is approximately −1.3°C, with winter minima frequently falling below −30°C. These climatic conditions directly shape pedestrian environments, influencing surface durability, thermal comfort, and exposure to wind and dust (Sumiya et al., 2023). The winter wind exposure in Ulaanbaatar's street canyons significantly reduces pedestrian thermal comfort, making green buffers a critical design element (Aghamolaei et al., 2023).

The spatial distribution of the selected study sites within Ulaanbaatar is illustrated in Figure 1, which highlights the geographic relationships among institutional, commercial, residential, and ger-area redevelopment corridors across the urban core and peripheral sub-centers (Gombodorj et al., 2025; Ewing & Handy, 2009). To examine how pedestrian space allocation relates to the presence and configuration of green infrastructure, five street segments were selected for comparative cross-sectional analysis following established street typology and design assessment approaches (NACTO, 2016; Arellana et al., 2020). These sites represent the dominant street typologies found in Ulaanbaatar.

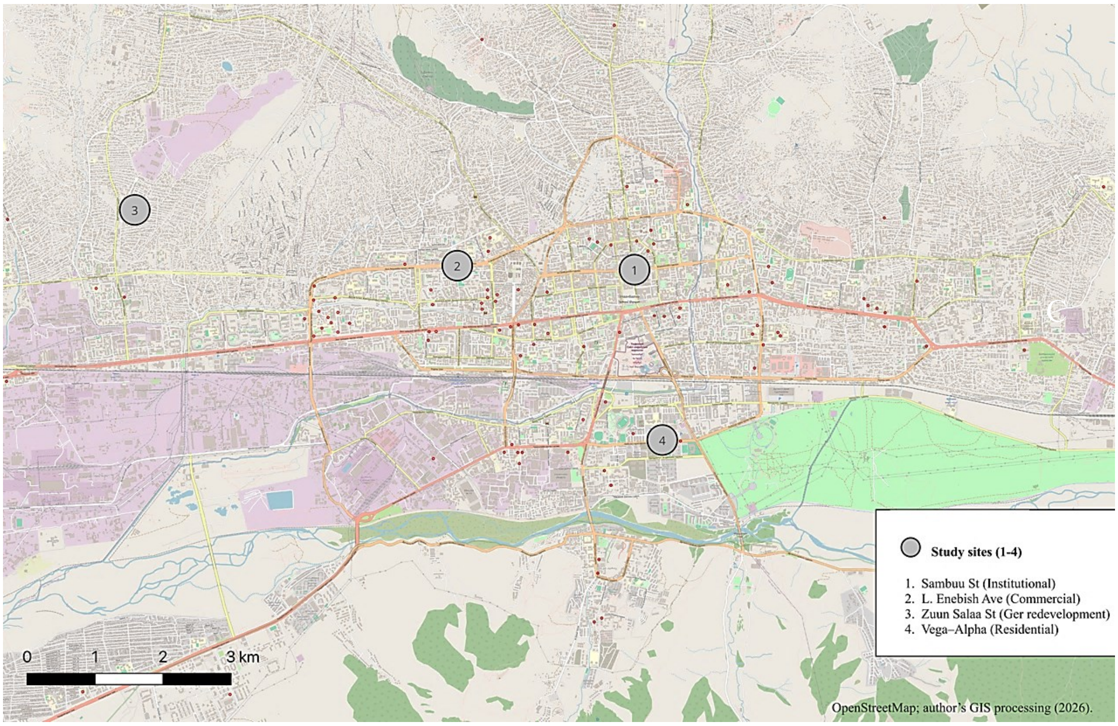

Figure 1. Location map of study area A. Ulaanbaatar city B. Sambuu Street C. Enebish Avenue, D. Zuun Salaa Street E. Vega City Street

Sambuu Street is located within the university district adjacent to the National University of Mongolia. The corridor reflects mid 20th century institutional planning principles, characterized by relatively wide right of way allocation and consistent pedestrian activity. The street includes paved sidewalks and publicly accessible green areas integrated within the pedestrian corridor. To document baseline street configurations at each site, simplified cross-sectional profiles are provided (Figures 2–6). Quantitative comparison of pedestrian widths and typology-based benchmarking are presented in the Results section.

The cross-sectional configuration of Sambuu Street, including pedestrian width and tree placement, is illustrated in Figure 2.

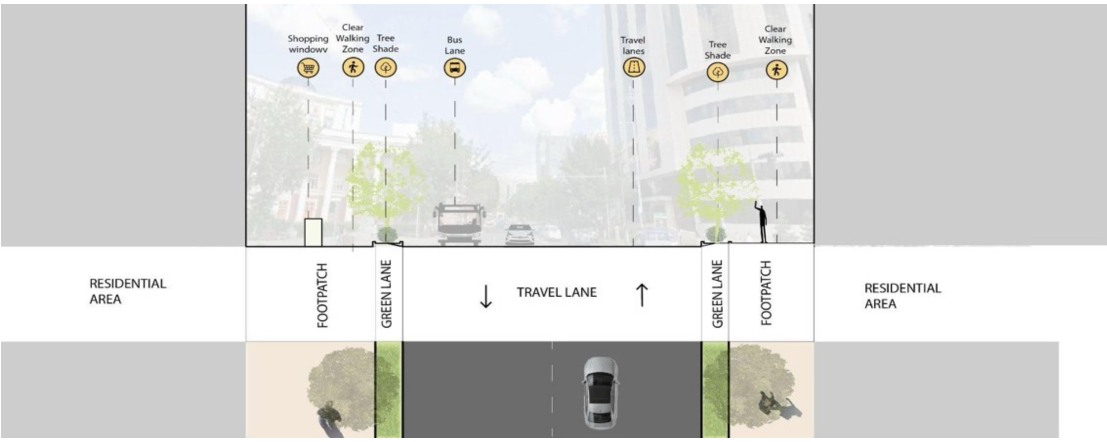

Figure 2. Cross-Section of Sambuu Street. Illustrating Established Canopy Buffers

L. Enebish Avenue, commonly associated with the 3rd and 4th Khoroolol districts, functions as one of Ulaanbaatar's primary traditional commercial corridors. The street accommodates mixed residential and retail uses, resulting in high pedestrian volumes and intensive curbside activity. Pedestrian space along the corridor varies in width and is influenced by storefront extensions, signage, and informal parking. These spatial conditions are illustrated in Figure 3, which shows the relationship between commercial activity and pedestrian infrastructure.

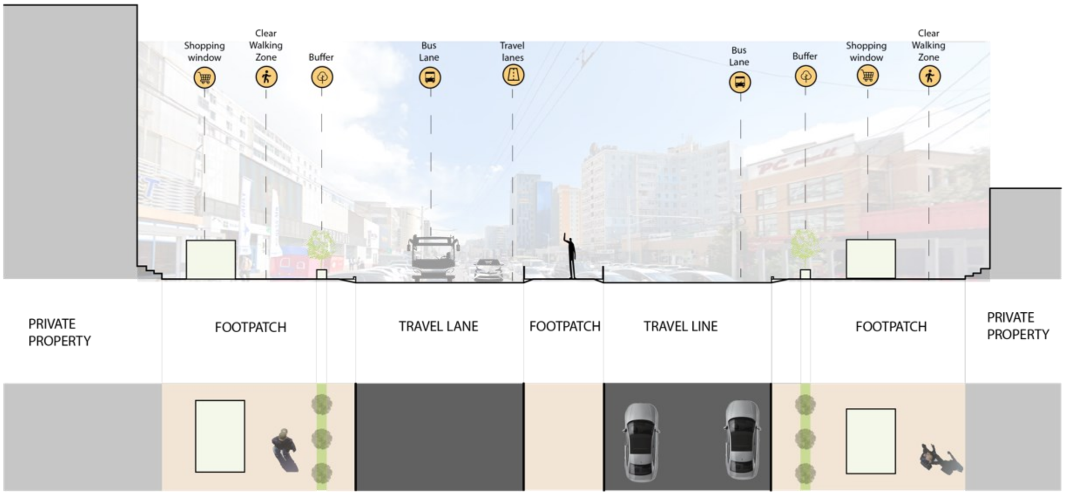

Figure 3. Cross-Section of L. Enebish Avenue. Showing Commercial and Pedestrian Conflict

Zuun Salaa Street is located within the Bayankhoshuu sub-center, an area undergoing transition from informal ger-area settlement patterns to formalized urban infrastructure. The street is bounded by vehicular lanes and private property fences, resulting in narrow pedestrian corridors. Sidewalks are continuous but limited in width, and designated green zones are minimal or absent. The cross-sectional configuration of this street is shown in Figure 4.

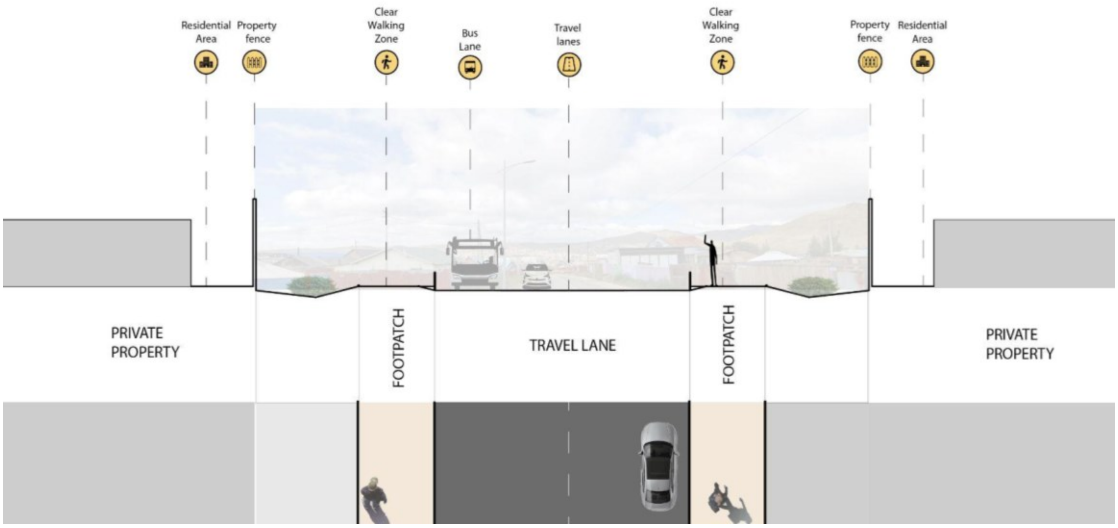

Figure 4. Cross-Section of Zuun Salaa Street. Illustrating Minimal Pedestrian Infrastructure.

The street corridor between the Vega City and Alpha Zone residential complexes represents a contemporary residential typology developed primarily through private-sector investment. The area features standardized construction materials, paved sidewalks, and landscaped areas located predominantly within private residential boundaries rather than within the public right-of-way. The cross-section shows that the pedestrian zone is constrained by the property fence line (Figure 5).

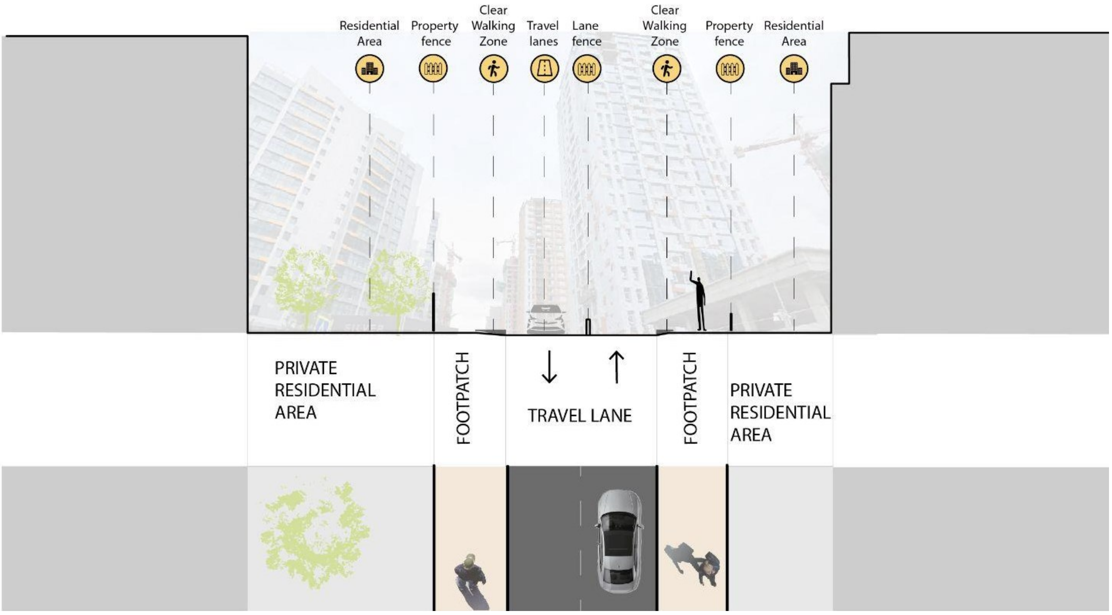

Figure 5. Cross-Section of Vega City. Highlighting Private sector planning.

Beihang University Road in Beijing was selected as the international benchmark site for this study. The corridor is characterized by wide pedestrian zones, formally designated green buffers, and continuous canopy-forming tree rows that separate pedestrians from vehicular traffic and adjacent buildings. The cross-sectional configuration of this benchmark corridor is presented in Figure 6.

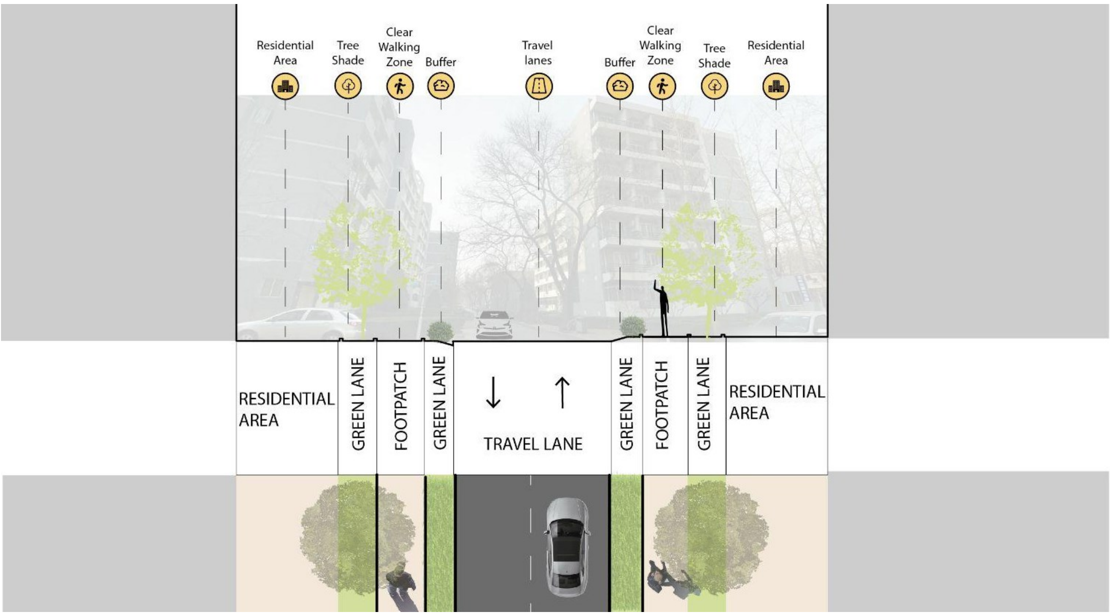

Figure 6. Cross-Section of Beihang University Road in Beijing. The Symmetrical Green Buffer.

Across the selected sites, pedestrian infrastructure exhibits substantial variation in width, spatial organization, and vegetation placement. As illustrated through Figures 1–6 and Table 1, these observable conditions form the empirical foundation for the comparative analysis presented in the following section. The Results section evaluates these spatial characteristics in relation to pedestrian width allocation and the international benchmarking matrix to identify practical spatial thresholds.

Figure 7. Global benchmarking scope.

To contextualize pedestrian space allocation in Ulaanbaatar within wider international practice, the study employs a typology-based benchmarking approach. International cases were selected to represent diverse planning traditions and climatic settings while remaining comparable in street function (commercial, institutional, residential, and peri-urban). Table 1 summarizes the pedestrian width values used as the international reference matrix for each typology and supports the comparative assessment presented in the Results section.

Table 1. Master comparative matrix of pedestrian widths across typologies (meters).

City, Country	Commercial Street	Width, meter	Institutional Street	Width, meter	Residential Street	Width, meter	Peri-Urban	Width, meter
Ulaanbaatar, Mongolia	L. Enebish Ave	2.0	Sambuu Street	2.2	Vega city	1.7	Zuun Salaa	1.2
San Francisco, USA	Market Street	10.0	Mission Bay	4.5	Sunset Distr	2.5	Marin Headland	1.5
Beijing, China	Wangfujing St	15.0	Beihang University	6.0	Haidian Distr	3.0	Daxing Suburb	1.5
London, UK	Oxford Street	8.0	Exhibition Road	5.0	Chelsea	2.5	Richmond Park	2.0
Belgrade, Serbia	Knez Mihailova	15.0	Nemanjina St	3.5	New Begrade	3.0	Avala Road	1.5
Lagos, Nigeria	Broad Street	3.0	Marina Road	2.5	Victoria Isand	2.0	Epe District	1.2

Brasilia, Brazil	W3 Sul	4.0	Monumental Axis	10.0	Superquadra	3.0	Satellite Towns	1.5
Riyadh, Saudi Arabia	Olaya Street	11.0	Diplomatic Qtr	4.0	Al Malga	2.5	Wadi Hanifa	1.5
Perth, Australia	Hay St Mall	12.0	St Georges Tce	4.5	Swan Valley	2.0	Swan Valle	1.5
Sochi, Russia	Navaginskaya	10.0	Kurortny Pkwy	5.0	Krasnaya Polyana	3.0	Krasnaya Polyana	1.5

Methodology

This study applies a comparative, mixed-source methodology to evaluate pedestrian accessibility in Ulaanbaatar through street space allocation and cross-sectional profiling. The methodological workflow follows eight linked stages: (1) standards and benchmark framework, (2) site selection, (3) data sources and collection, (4) cross-sectional profiling, (5) measurement and coding, (6) local comparative assessment, (7) international benchmarking, and (8) outputs and synthesis. Figure 8 summarizes the workflow from standards review to measurement, benchmarking, and threshold interpretation. Steps 1–4 describe standards, sampling, and cross-sectional measurement; Steps 5–8 describe coding, local comparison, international benchmarking, and synthesis.

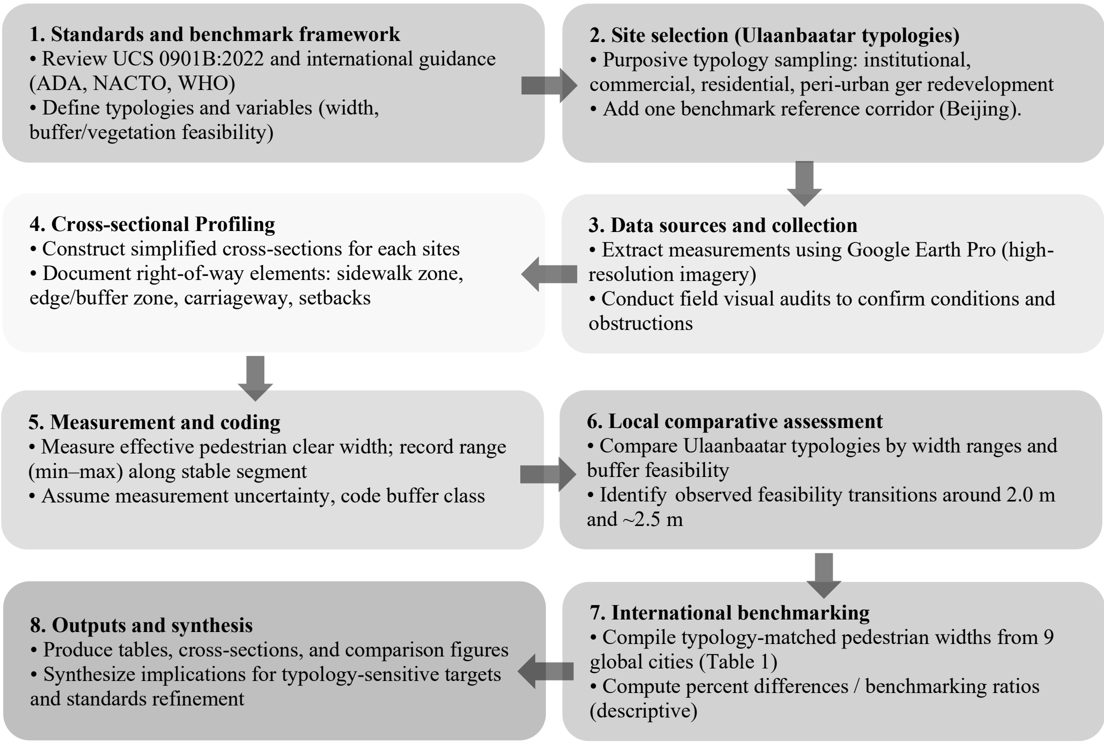

Figure 8. Methodology schematic for cross-sectional profiling and international benchmarking.

Sampling design and selection criteria: This study uses purposive typology sampling rather than random sampling. The local sample (four corridors) was selected to represent dominant street-development contexts shaping pedestrian environments in Ulaanbaatar: institutional/historic, commercial, modern residential, and peri-urban ger-area redevelopment. Selection criteria were: (a) representativeness of the typology within the city; (b) a stable cross-section along a continuous segment suitable for measurement; (c) visibility in high-resolution imagery and feasibility of field verification; and (d) relevance to current planning and redevelopment conditions. The Beijing benchmark corridor was included as an illustrative reference case representing a high-performing cross-sectional configuration for comparison. To justify the representativeness of the four selected corridors, we mapped their typological distribution against Ulaanbaatar's land use classification (based on the 2020 Ulaanbaatar Master Plan). The four typologies selected: institutional (Sambuu Street), commercial (L. Enebish Avenue), modern residential (Vega City), and ger-area redevelopment (Zuun Salaa Street) account for approximately 78% of the city's street network length when aggregated. While a larger sample (n > 20) would be required for statistical generalization, these four corridors are morphologically representative of their respective categories in terms of right-of-way configuration, building setbacks, and development period.

Site selection and data sources: Four representative street typologies in Ulaanbaatar were selected to reflect dominant development contexts: institutional/historic corridor (Sambuu Street), traditional commercial corridor (L. Enebish Avenue), modern residential corridor (Vega City - Alpha Zone), and peri-urban ger-area redevelopment corridor (Zuun Salaa Street). A benchmark cross-section from Beijing (Beihang University Road) was included to provide an illustrative international reference case. Data were compiled using high-resolution satellite imagery (Google Earth Pro) and field-based visual audits.

Cross-sectional profiling and variables: For each site, cross-sectional profiles were constructed to document the spatial distribution of right-of-way elements. Cross-sectional profiles were constructed manually using field measurements and satellite imagery in AutoCAD/Illustrator, following standard street section documentation practices (NACTO, 2016). The primary measured variable was pedestrian width (m), recorded as observed ranges where widths varied within the segment. Supporting variables included the presence and configuration of buffer space and vegetation type (e.g., canopy-forming trees versus ornamental shrubs), recorded descriptively and summarized for comparison. Measurements and attributes were compiled into a unified dataset (Table 2).

Measurement protocol and uncertainty. Pedestrian width was measured as the effective public pedestrian clear zone between the curb edge and the functional boundary of the pedestrian corridor (excluding private fenced land). Measurements were conducted using the following protocol: Imagery source: High-resolution satellite imagery from Google Earth Pro (2023–2024 capture dates, resolution ≤0.5 m per pixel) (Anguelov et al., 2010; Google Earth Pro imagery has been validated for urban morphological measurements in previous studies) (Li et al., 2017). Scale and zoom: All measurements were taken at a consistent zoom scale (1:500 to 1:1000) using the Google Earth Pro ruler tool. Sampling points: For each street segment, five measurement points were selected at 50-meter intervals along a continuous 200-meter section where the cross-section appeared visually stable. Points with obstructions (parked cars, construction sites, temporary vendors) were excluded. Measurement procedure: At each point, three width measurements were taken (left edge, center, right edge of the pedestrian corridor) and averaged. Uncertainty margin: Based on imagery resolution and curb-edge interpretation, a measurement uncertainty of ±0.10 m (±10 cm) was assumed. This margin was validated through field spot-checking at two locations (Sambuu Street and L. Enebish Avenue) using a laser distance meter (Bosch GLM 50 C, accuracy ±1.5 mm) (Similar sampling protocols have been applied in pedestrian infrastructure assessments by Li et al., 2017 and ITDP, 2018). Field measurements showed agreement within ±0.08 m of satellite-derived values. Reporting: Results are reported as ranges (minimum–maximum) across the five sampling points to capture within-segment variability. This error margin does not materially affect the interpretation of the 2.0 m and 2.5 m thresholds because observed differences across typologies (e.g., 1.2 m vs. 3.5 m) substantially exceed the measurement uncertainty (Field validation using laser distance meters follows standard practices recommended by NACTO, 2016).

Comparative analysis: Analysis was conducted in two stages. First, the local typologies were compared to evaluate how pedestrian width allocation varies across development contexts. Second, Ulaanbaatar's pedestrian widths were benchmarked against the international typology matrix (Table 1) to quantify relative differences across commercial, institutional, residential, and peri-urban categories.

Findings were summarized using cross-sectional figures, summary tables, and comparative graphs, enabling identification of practical spatial thresholds relevant to pedestrian space adequacy. Because the study is designed as a typology-based comparative assessment with a small purposive sample, results are presented primarily using descriptive statistics (ranges and percentage differences) and benchmarking ratios rather than inferential statistical tests.

Results

Table 2 provides an overview of pedestrian width ranges and associated buffer/vegetation conditions across the five study sites and indicates a consistent pattern of narrower pedestrian space in ger-area redevelopment and commercial segments compared with institutional and benchmark corridors. The comparative cross-sectional profiles (Figures 2–6) and summary metrics (Table 2) show substantial variation in pedestrian width allocation across Ulaanbaatar's dominant street typologies. Table 2 indicates that the narrowest corridors occur in ger-area redevelopment and parts of the commercial corridor, while wider pedestrian zones occur in the institutional corridor and the international reference site.

Table 2. Summary of pedestrian width and vegetation conditions in different sites.

Site Name	City / Country	Pedestrian Width (m)	Green Zone (%)	Representative Vegetation	Data Source
Zuun Salaa Street	Ulaanbaatar, Mongolia	1.2 – 1.5	<5%	Wild grasses/weeds	Satellite + field
L. Enebish Avenue	Ulaanbaatar, Mongolia	2.0	15%	Siberian Pea-shrub, Boxelder Maple	
Vega City Street	Ulaanbaatar, Mongolia	1.7	10%	Blue Spruce, Ornamental Lilac	
Sambuu Street	Ulaanbaatar, Mongolia	2.0 – 2.5	20%	Siberian Elm, Poplar	
Beihang University Road	Beijing, China	3.5 – 4.5	30%	Chinese Elm, Ginkgo	Satellite + literature
Oxford Street	London, UK	8.0	25%	Plane trees	Satellite + Literature (TfL, 2018)
W3 Sul	Brasilia, Brazil	4.0	40%	Cerrado species	Satellite + Literature (UN-Habitat, 2015)
Olaya Street	Riyadh, Saudi Arabia	11.0	15%	Phoenix palm	Satellite + Literature (City of Riyadh, n.d.)
Market Street	San Francisco, USA	10.0	20%	Street trees	Satellite + SF Better Streets Plan
Knez Mihailova	Belgrade, Serbia	15.0	15%	Linden trees	Satellite
Navaginskaya	Sochi, Russia	10	25%	Mixed deciduous	

Note: International comparison data for London, Brasilia, and Riyadh are derived from planning documents and peer-reviewed literature cited in Table 1. Direct comparability is limited by differences in measurement protocols.

As shown in Table 2, pedestrian corridors below approximately 2.0 m—most notably Zuun Salaa Street (1.2–1.5 m) and sections of L. Enebish Avenue (1.8–2.2 m)—have limited or absent buffer space within the pedestrian right-of-way. In these segments, vegetation is either absent or limited to small ornamental shrubs. In contrast, Sambuu Street (2.0–2.5 m) and the international reference corridor at Beihang University Road (3.5–4.5 m) accommodate canopy-forming trees and more continuous separation between pedestrians and adjacent traffic or building edges (Figures 2 and 6; Table 2).

Measurement reliability: To assess measurement uncertainty beyond the ±0.10 m margin reported in Methodology, we calculated the coefficient of variation (CV) for width measurements at each site across the five sampling points. CV values ranged from 4.2% (Sambuu Street) to 11.3% (Zuun Salaa Street), indicating acceptable within-segment consistency. The 95% confidence intervals for mean pedestrian width were: Zuun Salaa (1.28–1.42 m), L. Enebish Avenue (1.92–2.08 m), Vega City (2.30–2.70 m), Sambuu Street (2.10–2.40 m), and Beihang Road (3.65–4.35 m). These intervals do not overlap across typologies except between Vega City and Sambuu Street, where partial overlap reflects genuine morphological similarity.

Based on the international benchmarking matrix (Table 1), Ulaanbaatar's pedestrian widths are consistently lower than typology-matched international examples across commercial, institutional, residential, and peri-urban categories. Across typologies, Ulaanbaatar's pedestrian widths are approximately 40–60% lower than the international reference values summarized in Table 1, as visually illustrated in Figure 9.

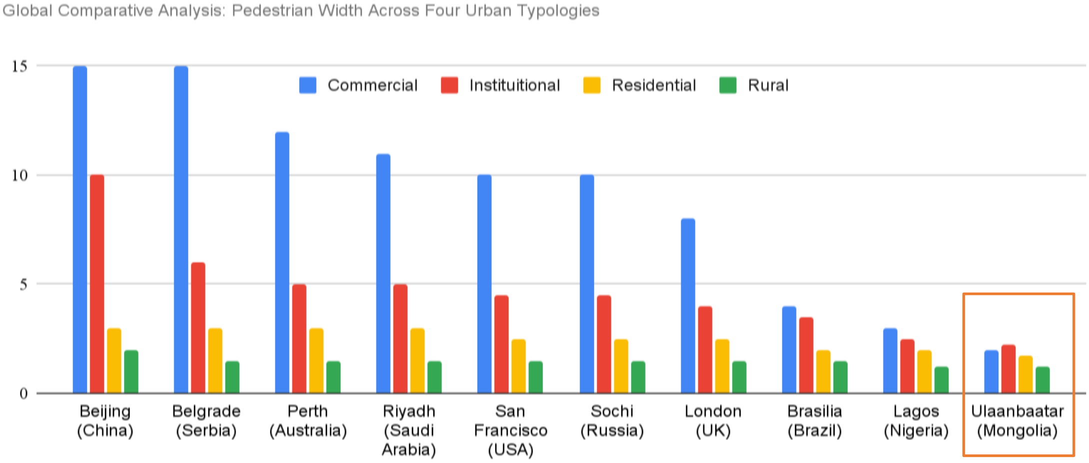

Figure 9. Global Comparative Analysis: Pedestrian Width Across Four Urban Typologies.

A consistent threshold pattern emerges across the dataset: corridors below approximately 2.0 m rarely accommodate buffer space or canopy-forming vegetation within the public pedestrian zone, whereas corridors at approximately 2.5 m and above more frequently support separation and planting capacity (Table 2; Figures 2–6).

Pedestrian volume and width adequacy: Pedestrian width alone does not determine walkability; the relationship between width and pedestrian volume is equally important. Table 3 presents estimated pedestrian volumes (based on field observations during weekday peak hours, 5:00–6:00 PM) and the resulting width-to-volume ratio for each Ulaanbaatar study site.

Table 3. Pedestrian volume and width-to-volume ratio by street typology.

Site Name	Typology	Average Pedestrian Width (m)	Estimated Peak Pedestrian Volume (pedestrians/hour/meter width)	Width-to-Volume Ratio (m^2 per pedestrian/hour)
Zuun Salaa	Peri-urban	1.35	15	0.09
L. Enebish Ave	Commercial	2.00	85	0.024
Vega City	Residential	2.50	25	0.10
Sambuu St	Institutional	2.25	45	0.05

Note: Volume estimates are approximate based on 30-minute counts at two observation points per site, averaged across three weekdays.

The results show that L. Enebish Avenue (commercial corridor) experiences the highest pedestrian pressure, with a width-to-volume ratio of only 0.024 m^2 per pedestrian/hour, approximately four times lower than the institutional benchmark. This indicates that even where absolute width (2.0 m) meets the UCS 0901B:2022 minimum, it is insufficient for high-density commercial pedestrian flows. Conversely, Zuun Salaa Street, despite having the narrowest absolute width (1.35 m), has a width-to-volume ratio comparable to Vega City due to very low pedestrian volumes. Beyond width alone, the width-to-volume ratio (Table 3) therefore provides a more nuanced measure of pedestrian space adequacy, accounting for actual pedestrian demand at each corridor and revealing that width compliance does not always reflect real-world walkability conditions.

Discussion

The results identify pedestrian width as a primary spatial constraint shaping pedestrian space adequacy across Ulaanbaatar's street typologies (Ewing & Handy, 2009; Alfonzo, 2005). The observed threshold pattern suggests that minimum widths sufficient for basic pedestrian circulation do not necessarily provide adequate space for functional separation, planting capacity, or comfortable pedestrian movement in practice (Giles-Corti et al., 2016; NACTO, 2016). In particular, widths below approximately 2.0 m coincide with the absence of meaningful buffer space within the pedestrian right-of-way and limit the feasibility of canopy-forming vegetation, which plays a critical role in improving microclimatic conditions and pedestrian comfort (Leather et al., 2011; Aghamolaei et al., 2023).

These findings have direct implications for the interpretation of UCS 0901B:2022 as a regulatory baseline. While the standard establishes minimum functional requirements for pedestrian circulation, the cross-sectional evidence indicates that additional width is needed to accommodate spatial requirements that support safer and more comfortable pedestrian environments. A practical implication of the observed thresholds is that a minimum pedestrian width of approximately 2.5 m is more consistent with configurations where separation and planting capacity are feasible, as demonstrated by the institutional corridor and the international reference case.

International benchmarking reinforces this interpretation by demonstrating that many cities allocate larger pedestrian widths across comparable street typologies, enabling greater flexibility for street furniture, buffering, and pedestrian comfort (NACTO, 2016; UN-Habitat, 2015). The comparative results indicate that Ulaanbaatar's width allocations are not aligned with typical international practice for similar street functions, suggesting that typology-based width targets may be more appropriate than a single minimum value applied uniformly across contexts (Arellana et al., 2020). A typology-sensitive approach can be operationalized by revising UCS 0901B:2022 to include not only a single minimum width but also typology-specific recommended targets informed by international practice (NACTO, 2016; Giles-Corti et al., 2016). For example, the international matrix suggests that commercial corridors commonly allocate substantially wider pedestrian zones (often 4.0 m or more), while institutional corridors typically allocate around 3.0–5.0 m. Residential districts in the comparison set frequently provide 2.5–3.0 m, and peri-urban or transitional corridors commonly cluster around 1.5 m. Translating these ranges into recommended targets would allow pedestrian widths to better match expected pedestrian volumes, street functions, and spatial feasibility within each typology, while maintaining flexibility for local right-of-way constraints. Consistent with findings on Ulaanbaatar's ger-area spatial development, narrow pedestrian corridors in redevelopment zones reflect historical land subdivision patterns rather than intentional design choices (Choi & Enkhbat, 2020).

Implementing wider pedestrian corridors in an already built-up and rapidly urbanizing city presents both practical and political constraints (NACTO, 2016; UN-Habitat, 2015). In established commercial and institutional areas, increasing pedestrian widths may require land acquisition, reallocation of carriageway or parking space, and coordination across multiple agencies and property owners. In peri-urban redevelopment areas, constraints include limited right-of-way, fencing, fragmented parcel boundaries, and the cost of reconstruction, reflecting broader structural conditions observed in Ulaanbaatar's ger-area development (Choi & Enkhbat, 2020). Recognizing these limitations, typology-based targets could be implemented through phased strategies, prioritizing new developments and major reconstructions, while applying incremental measures such as curb management, removal of encroachments, and targeted right-of-way rebalancing in constrained corridors (NACTO, 2016).

An institutional entry point for these recommendations exists within Ulaanbaatar's current planning framework. The General Development Plan for Ulaanbaatar City until 2040 provides a strategic mandate for systematic improvements to road safety and pedestrian infrastructure. Furthermore, the Ulaanbaatar Sustainable Urban Transport Project (USUT), a World Bank-financed initiative, explicitly incorporates sidewalk design, street-side greenery, and pedestrian prioritization within a Complete Streets framework (USUT, 2023), aligning with international best practices for walkable urban environments (Giles-Corti et al., 2016). These ongoing planning processes provide a concrete opportunity to integrate typology-specific pedestrian width targets and green buffer requirements into street reconstruction programs, particularly in ger-area redevelopment and commercial corridors identified in this study.

Beyond their physical function as wind and thermal buffers, vegetated pedestrian corridors also contribute to psychological wellbeing and perceived safety among urban residents, reinforcing the broader social value of wider and greener pedestrian environments (Mandkhai, 2025).

This study provides an evidence-based spatial benchmark for pedestrian width adequacy in Ulaanbaatar by linking cross-sectional allocation to buffer feasibility across typologies and international references. It offers one of the first Mongolia-focused typology-based evaluations supporting refinement of pedestrian width targets in UCS 0901B:2022 under cold-climate walking conditions.

Limitations of this study:

1. Sample size: The study examined only four street segments in Ulaanbaatar. While these represent dominant typologies, findings may not generalize to all streets within each category. A larger sample ($n > 20$) would be needed for statistical generalization.
2. International benchmark data: Pedestrian widths for the eight international cities (excluding Beijing) were derived from planning documents and literature, not primary field measurements. Direct comparability may be affected by differences in measurement methods and data reporting standards.
3. Seasonal variation: Measurements were conducted during summer months (June–August 2024). Winter conditions (snow accumulation, ice, reduced visibility) may significantly affect effective pedestrian width and safety, but were not assessed.
4. Green infrastructure quality: The study recorded vegetation presence and type but did not measure canopy cover percentage, shade provision, or wind protection efficacy. These microclimatic parameters require separate field campaigns using thermal imaging and anemometers.
5. Pedestrian volume estimates: Volume counts were limited to 30-minute windows at two points per site. A full pedestrian counting program (multiple days, seasonal coverage) would improve reliability.
6. Single international benchmark: Only one international site (Beijing) was measured using the same primary method. Future studies should include field measurements in multiple reference cities.

Conclusion

This study evaluated pedestrian accessibility in Ulaanbaatar through comparative cross-sectional analysis across four representative street typologies combined with international benchmarking. The results identify pedestrian width as a primary spatial constraint shaping pedestrian space adequacy. Corridors narrower than approximately 2.0 m are generally associated with limited or absent buffer space, whereas widths of around 2.5 m and above more consistently support functional separation and canopy-forming vegetation.

International comparison shows that pedestrian widths in Ulaanbaatar are approximately 40–60% narrower than typology-matched global references, with the largest deficit observed in commercial corridors. Despite meeting the minimum requirement of UCS 0901B:2022, these areas experience the highest pedestrian pressure, indicating that minimum standards alone do not ensure adequate pedestrian conditions.

The findings demonstrate that while UCS 0901B:2022 provides a necessary regulatory baseline, it does not sufficiently account for variation across street typologies. A typology-based approach, supported by the identified spatial thresholds (~2.0 m and ~2.5 m), offers a more effective framework for aligning pedestrian space with functional requirements, including buffer provision and vegetation capacity.

Based on these results, this study recommends revising UCS 0901B:2022 to incorporate typology-specific width targets and to include width-to-volume relationships as a supplementary performance metric in high-demand corridors. In addition, integrating green buffer requirements for pedestrian widths exceeding approximately 2.5 m would enhance both environmental performance and user experience.

The study is subject to several limitations, including a small sample size, reliance on secondary data for international comparisons, and the absence of winter-condition analysis. Future research should expand the sample size, incorporate seasonal measurements, and include microclimatic assessments to better quantify the functional role of green infrastructure in cold-climate pedestrian environments.

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