Spatial Assessment of Superblock and Miniblock Implementation Potential in Ulaanbaatar Using GIS and Open Geospatial Data

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Abstract: *Rapid urbanization in Ulaanbaatar has intensified traffic congestion, reduced pedestrian accessibility, and limited the availability of multifunctional public spaces. This study explores the potential of applying the superblock and miniblock model as a human-centered urban planning approach tailored to the city's unique urban form. Using open geospatial datasets and ArcGIS Pro, potential blocks were generated from OpenStreetMap road networks and building footprints. Each block was evaluated against four quantitative criteria: geometric size (area and perimeter thresholds), building coverage ratio (≥30% built-up area), population density (≥100 people/ha, derived from disaggregated khoroo-level census data), and land tenure composition (ratio of public to private ownership). Additional analysis integrated green space layers to assess environmental opportunities. The results identified 37 miniblocks and across Ulaanbaatar as spatially feasible for transformation. These blocks demonstrate compact urban form, high residential density, and significant potential to expand pedestrianized areas and green infrastructure. The findings suggest that implementing superblock-based design in Ulaanbaatar can improve urban livability by reducing car dependency, enhancing walkability, and increasing the share of green and public space. Overall, this research contributes a transferable GIS-based framework for superblock identification in Asian cities, emphasizing the value of open geospatial data and spatial analysis in supporting evidence-based urban design decisions.*

Keywords: Superblock, Miniblock, GIS, Urban planning, Building coverage, Population density, Green space, Ulaanbaatar

Introduction

Ulaanbaatar, the capital of Mongolia, has undergone rapid urbanization in recent decades, accompanied by population growth, expansion of residential areas, and increasing dependence on private vehicles. These dynamics have resulted in persistent traffic congestion, environmental degradation, and a significant reduction in pedestrian-friendly and multifunctional public spaces. The challenges faced by Ulaanbaatar mirror those of many rapidly growing Asian cities, where unplanned expansion and insufficient infrastructure limit sustainable urban development.

Globally, alternative planning models have been explored to address such issues. Among them, the superblock concept, originally developed in Barcelona, offers a promising human-centered approach by restructuring street networks, restricting vehicular movement within blocks, and enhancing public and green spaces. Subsequent research, such as Eggimann (2022), has advanced this model by developing transferable, data-driven methodologies that assess block suitability using open spatial datasets and quantitative indicators. These methods have been tested across multiple cities, demonstrating their adaptability and value in sustainable mobility and urban livability studies.

In this context, Ulaanbaatar provides a critical case for applying and adapting the superblock methodology. Unlike European examples, the city's unique conditions—cold climate, mixed land tenure systems, high residential density, and uneven distribution of green areas—require localized assessment. This study therefore seeks to evaluate the spatial feasibility of superblocks and miniblocks in Ulaanbaatar using open geospatial datasets and GIS-based spatial analysis.

The specific objectives of this research are: (1) to generate potential urban blocks from existing street networks, (2) to evaluate their suitability based on geometric size, building coverage, population density, and land tenure structure, and (3) to identify feasible locations for transforming into pedestrian-oriented, multifunctional spaces. By integrating these analyses, the study contributes both to the scientific discourse on sustainable urban models in Asia and to practical strategies for improving Ulaanbaatar's urban environment.

Literature Review

The superblock model has emerged as a significant paradigm in contemporary urban studies, particularly in response to issues of traffic congestion, pollution, and the decline of pedestrian accessibility. Originating in Barcelona, the concept redefines urban mobility by restricting through-traffic within designated blocks, redistributing street space to pedestrians and cyclists, and integrating green and multifunctional areas into the urban fabric (Rueda, 2019). This approach has been widely discussed as a transformative strategy for achieving sustainable mobility and human-centered urban design.

Building upon these foundations, Eggimann (2022) advanced a transferable framework to evaluate superblock feasibility through quantitative spatial indicators. The study applied geometric criteria, building coverage, and population density to assess block suitability across multiple cities, demonstrating the adaptability of the model beyond its European origin. These contributions highlight the importance of data-driven approaches in evaluating the scalability of superblocks in different urban contexts.

GIS and remote sensing technologies have been instrumental in operationalizing such methodologies. Studies across Asia and Europe have used OpenStreetMap (OSM), census data, and satellite-derived land cover information to assess accessibility, land-use efficiency, and the distribution of public space (Sharifi, 2020; Angelidou et al., 2021). These tools enable researchers to combine geometric and demographic indicators, thereby offering evidence-based frameworks for urban transformation.

While Ulaanbaatar has limited prior research on superblocks, existing literature emphasizes the city's challenges of unplanned expansion, high car dependency, and insufficient green infrastructure (Batbuyan, 2017; Enkhtuul & Erdenetuya, 2020). Integrating international models into this context requires adaptation to Mongolia's unique conditions, such as extreme climate, mixed land tenure systems, and uneven service accessibility.

In summary, the reviewed literature underscores both the global potential of the superblock methodology and the necessity of localized adaptation. By applying and contextualizing Eggimann's framework to Ulaanbaatar, this study addresses a research gap while contributing to broader discussions of sustainable urban planning in rapidly growing Asian cities.

Methodology

This study applies a GIS-based framework to evaluate the spatial feasibility of implementing superblocks and miniblocks in Ulaanbaatar. The methodology builds on the transferable approach proposed by Eggimann (2022), with modifications to fit the local urban form and available datasets. The workflow consisted of several sequential steps, each supported by open geospatial data and spatial analysis tools in ArcGIS Pro.

1. **Data Collection and Preparation**

OpenStreetMap (OSM) road network and building footprint data were extracted and cleaned to serve as the base layers. Administrative boundary shapefiles and khoroo-level population census data from the National Statistical Office of Mongolia were integrated.

Additional datasets on land tenure (ownership and possession categories) and green space distribution were included to extend the analysis.

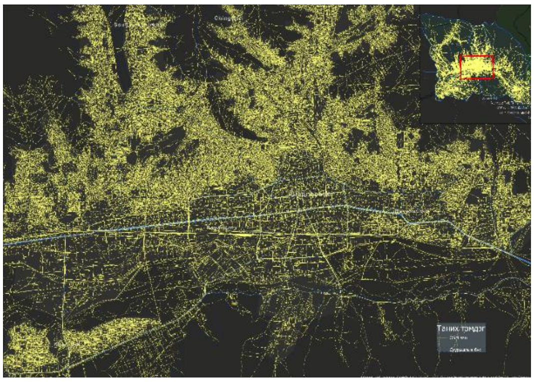

Figure 2. OpenStreetMap-based road network of Ulaanbaatar (Source: OSM, 2025).

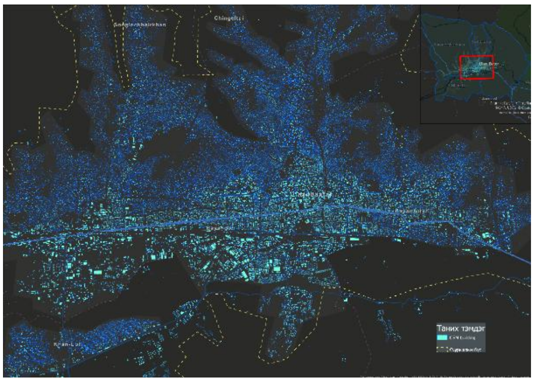

Figure 1. OpenStreetMap-based road network of Ulaanbaatar (Source: OSM, 2025).

2. Potential Block Generation

The street network polyline layer was polygonized using the *Feature to Polygon* tool to produce closed urban blocks. These blocks formed the spatial units of analysis.

Figure 3. OSM road network data with functional classification (Source: OSM, 2025).

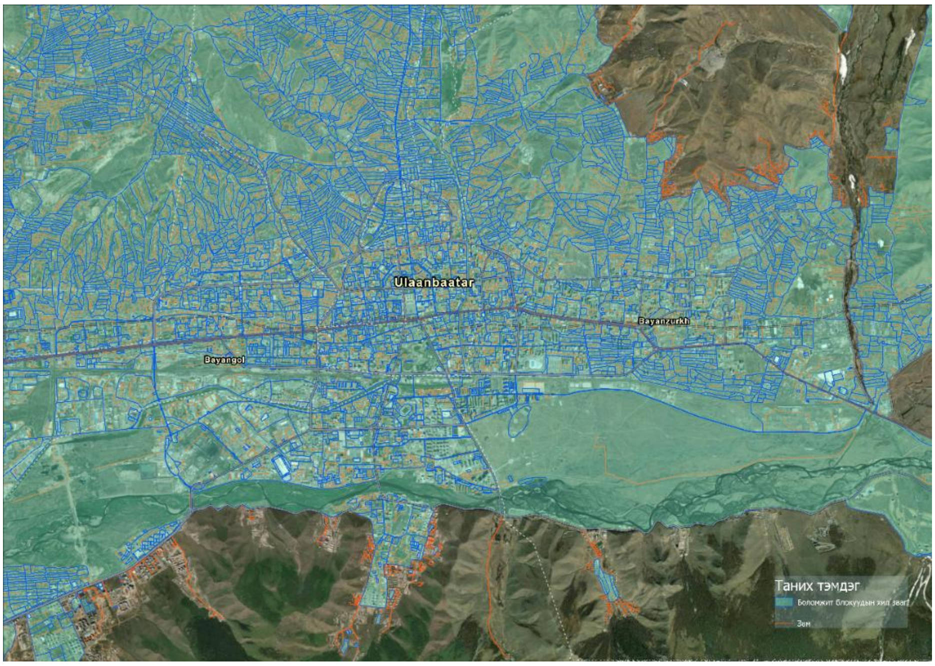

Figure 4. Primary urban block structure generated from the OpenStreetMap (OSM) street network (Source: Author, 2025).

3. Geometric Filtering

For each block, geometric attributes were calculated using *Calculate Geometry Attributes*. Blocks were classified according to area and perimeter thresholds:

- Miniblock criteria : $40{,}000\, m^2 \leq Area < 160{,}000\, m^2;\ Perimeter \geq 850\, m$
- Superblock criteria : $Area \geq 160{,}000\, m^2;\ Perimeter \geq 1280\, m$

4. Building Coverage Ratio

Block polygons were intersected with building footprints using the *Tabulate Intersection* tool. Building coverage was then computed as:

$$Coverage\ (\%) = \frac{Total\ Building\ Area\ within\ Block}{Block\ Area} \times 100$$

Selection threshold:

$$Coverage \geq 30\%$$

5. Population Density Estimation

Khoroo-level census data were spatially disaggregated by overlaying with blocks. Weighted population for each block was derived as:

$$Weighted; Pop = \frac{Intersect\ Area}{Khoroo; Area} \times Khoroo\ Pop$$

Total block population was calculated by summing all intersected portions, and population density was expressed as:

$$Density = \frac{Population}{Block\ Area/10{,}000} \quad \left(\frac{people}{ha}\right)$$

A density threshold of ≥100 people/ha was applied.

5. Land Tenure Assessment

Ownership and possession data were intersected with blocks to determine the proportion of public versus private land. This step provided insight into governance and implementation feasibility.

$$Ownership\ Ratio = \frac{Public\ Land\ Area}{Total\ Block\ Area}$$

Blocks with balanced tenure ($0.3 \leq ratio \leq 0.7$) were considered more feasible.

7. Green Space Integration

Green space polygons were overlaid with candidate blocks to identify areas with potential for environmental enhancement and improved livability.

$$Green\ Ratio = \frac{Green\ Space\ Area}{Total\ Block\ Area} \times 100$$

8. Final Selection of Suitable Blocks

Blocks satisfying all four criteria—geometric thresholds, coverage ratio, population density, and land tenure suitability—were classified as *Final Miniblock* or *Final Superblock*.

This methodological framework demonstrates the application of open geospatial data and GIS-based spatial analysis in urban planning. It ensures transparency, replicability, and adaptability for other Asian cities facing similar urban challenges.

Results and Discussion

The spatial analysis identified a total of **37 candidate blocks**, consisting of **37 miniblocks** that satisfied the established criteria. Geometric filtering reduced the initial polygonized street network to approximately 28% of all blocks, indicating that only a fraction of Ulaanbaatar's current street fabric aligns with international benchmarks. Building coverage assessment showed that the majority of selected blocks exceeded the 30% threshold, with an average coverage ratio of 38.5%, highlighting their compact urban form. Population density calculations revealed that suitable blocks ranged from 110 to 210 people per hectare, with the highest concentrations observed in the city center and older residential districts. Land tenure analysis demonstrated that about 65% of candidate blocks had a balanced mix of public and private ownership, whereas industrial and institutional zones were less suitable due to restrictive ownership patterns. Integration of green space data revealed that only 40% of selected blocks contained existing green areas, pointing to significant opportunities for ecological enhancement.

These results underscore both opportunities and constraints for adopting the miniblock model in Ulaanbaatar. On the one hand, high-density residential blocks with compact forms align well with the model's objectives of reducing car dependency and enhancing pedestrian environments. On the other hand, fragmented land tenure and limited green infrastructure pose practical challenges to implementation. Compared with European case studies such as Barcelona, Ulaanbaatar's blocks tend to be larger and less evenly distributed, requiring tailored adjustments to threshold criteria. The findings confirm that while the methodology is transferable, localized calibration is essential for effective application in the Mongolian context.

Figure 5. Map of potential blocks (Source: Author, 2025)

Conclusion and Recommendation

This study demonstrated the feasibility of applying a GIS-based framework to identify superblock and miniblock opportunities in Ulaanbaatar. By integrating open geospatial data, census information, and urban land-use datasets, the research highlighted 52 blocks with strong potential for transformation into pedestrian-oriented, multifunctional urban spaces. These results provide a first evidence-based mapping of superblock suitability for the Mongolian capital.

The main conclusions are:

1. Ulaanbaatar possesses a sufficient number of compact, high-density blocks that meet international superblock criteria.
2. Green infrastructure is underrepresented within candidate blocks, but integration offers a clear opportunity for enhancing livability.
3. Land tenure composition plays a critical role in feasibility, with mixed ownership being more conducive to intervention than areas dominated by industrial or state property.

Based on these findings, the following recommendations are made:

- Policy Integration: Municipal planning authorities should integrate the superblock framework into long-term urban development plans.
- Pilot Implementation: Select 2–3 candidate blocks in the city center for pilot projects to test practical feasibility and community response.
- Green Space Enhancement: Prioritize the creation and expansion of green areas within selected blocks to maximize environmental benefits.
- Public Engagement: Engage residents and stakeholders early in the process to address concerns related to mobility, parking, and accessibility.

Overall, adopting superblock-inspired planning in Ulaanbaatar could significantly improve urban sustainability, mobility, and quality of life, provided that local conditions and governance structures are carefully considered.

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