Delimitation of Community Life Circles and Comprehensive Measurement of Their Construction Level: A Case Study of Urumqi (Postprint)

Authors: Tang Yuting

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Abstract

Community life circles are intimately connected to residents' daily lives, constituting the fundamental unit for urban grassroots public service facility construction and serving as a crucial instrument for urban renewal. Scientifically delineating the boundaries of community life circles and comprehensively measuring their development level provides theoretical insights for advancing community life circle construction and achieving efficient allocation of public resources, while offering novel perspectives and empirical cases for research on the relationship between geographic environments and resident behavior. This paper adopts a research framework of scientific delineation and construction level evaluation of life circles, exploring optimization methods for community life circle demarcation by integrating walking planning spatiotemporal circles with Mapbox spatiotemporal circle data. It constructs a comprehensive measurement indicator system for life circle construction level from dimensions including facility layout, spatial accessibility, and resident satisfaction, and conducts an empirical study using Urumqi as a case study. The results demonstrate that: (1) Integrating walking planning spatiotemporal circles and Mapbox spatiotemporal circle data to delineate life circle boundaries can enhance the timeliness and accuracy of boundary determination. (2) Facility layout density and per capita availability exert significant influences on life circle construction level. (3) In Urumqi, the 15-minute walking life circle exhibits an average radius of 812.75 m and an average area of 2.10 km^2; the construction level in old districts surpasses that in newly developed areas, and the construction level of commercial service facilities exceeds those of health management, education, transportation, and other facility categories; insufficient facility quantity and uneven spatial distribution constitute the primary causes of these disparities.

Full Text

Preamble

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Spatial Scope of Community Living Circle and Comprehensive Measurement Method of Construction Level: Urumqi City as an Example

TANG Yuting[1,2], DU Hongru[1,2]
[1] Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi, Xinjiang 830011, China
[2] College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: Community living circles are closely related to residents' daily lives, serving as the fundamental unit for constructing urban grassroots public service facilities and a critical lever for urban renewal. Scientifically delineating the spatial scope of community living circles and comprehensively measuring their construction level provides theoretical exploration for advancing community living circle development and achieving efficient allocation of public resources, while offering new perspectives and case studies for research on the relationship between geographic environment and resident behavior. Based on the research framework of scientifically delineating living circle scope and evaluating construction level, this study explores an optimized method for community living circle delineation by merging walking route planning circles and Mapbox spatiotemporal circles. It constructs a comprehensive measurement index system for living circle construction level from dimensions including facility layout, spatial accessibility, and resident satisfaction, and conducts empirical research using Urumqi City as a case study. The results indicate: (1) Merging walking route planning circles and Mapbox spatiotemporal circles to delineate living circle scope can improve the timeliness and boundary accuracy of the division results. (2) Facility density and per capita availability have a more significant impact on living circle construction level. (3) The average radius of 15-minute living circles in Urumqi is 812.75 m, with an average area of 2.10 km^2. The construction level in old urban areas is higher than in newly built areas, and commercial service facilities show higher construction levels than health management, education, travel, and other facility types. Insufficient facility quantity and unbalanced layout are the main causes of these differences.

Keywords: community living circle; public service facilities; division method; evaluation system; Urumqi City

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Introduction

China' s urbanization is currently transitioning from a rapid growth phase to a quality improvement phase, representing a critical transformation period to-

ward high-quality development. Meeting people's growing material and cultural needs has become the key to urban high-quality development. Community living circles are intimately connected to residents' lives, constituting the basic unit for urban grassroots public service facility construction and an important instrument for urban renewal and quality enhancement of existing stock. The *Standard for Urban Residential Area Planning and Design* establishes 5-minute, 10-minute, and 15-minute living circles and residential neighborhoods as the core concepts for residential spatial organization, replacing the long-used system of residential districts, residential quarters, and clusters. This emphasizes resident demand as the guiding principle for rational public service facility layout. The *Spatial Planning Guidance to Community Life Unit* explicitly proposes construction requirements for public service facilities at different living circle levels. Cities including Shanghai, Jinan, and Xinjiang have comprehensively advanced "15-minute living circle" construction, successively issuing construction guidelines, technical standards, and specific action work guides.

The concept of living circles was first proposed in Japanese planning in the 1960s, and subsequently, many countries in Asia and Europe have applied the living circle concept in practical construction. Carlos et al. consider living circles as dense, diverse communities from a broad urban perspective, encompassing six basic functions: living, working, commerce, care, learning, and enjoyment. With changing times, the application of information and communication technologies has further characterized community living circles by density, proximity, diversity, and informatization. In the post-pandemic era, scholars have emphasized the importance of time costs for accessing living circle services, advocating that residents should be able to walk or cycle to obtain all basic necessities within 15 minutes. The community living circle concept has been further expanded in China, achieving localized transformation and application. The *Spatial Planning Guidance to Community Life Unit* defines community living circles as basic units that meet the work and life needs of urban and rural residents throughout their life cycles within an appropriate daily walking range, covering six functions: community services, employment guidance, housing improvement, daily travel, ecological leisure, and public safety. Facilities are classified according to functional characteristics into basic security type, quality improvement type, and characteristic type, with different facility construction recommendations proposed for urban and township community living circles.

Current domestic research on community living circles remains in continuous exploration and improvement. Scholars' research focuses primarily on three aspects: (1) Spatial scope division methods. Big data, with its high precision advantage, has gradually replaced fixed-distance methods for dividing living circle scope. Mobile signaling data, resident behavior survey data, and walking planning data are widely used. Mobile signaling data lacks travel mode attributes and is often combined with resident activity behavior survey data or used to divide living circle scope according to travel frequency. Chai Yanwei et al. delineated resident living circle scope based on GPS data and activity log data. Walking planning data represents residents' walking travel chains and is

often spatialized using two-dimensional grids. Case studies from Xi' an show that grid size selection affects results: using 200 m grids yields an average living circle area of 1.34 km^2, while 200-350 m grids yield 1.75 km^2, indicating certain differences between these calculation results.

(2) Living circle construction level evaluation. Existing research has quantified community living circle construction level using indicators such as facility coverage rate and density based on actual public service facility construction conditions. As research deepens, perspectives have shifted from spatial environmental elements to resident perception. Shen Yue et al. analyzed resident behavior characteristics and their interaction with the environment through space-time behavior surveys, while Zhou Xian considered residents' walking willingness as one of the evaluation bases for living circle construction level. However, research incorporating residents' satisfaction with urban public services and sense of security as evaluation points remains lacking.

(3) Community living circle optimization allocation research. Chen Lufeng et al. proposed localized facility layout schemes or optimization plans based on population density, facility functions, and accessibility differences. Community living circles represent a complex of geographic environment and residents' production and life. With national requirements for "people build their own cities" and urban high-quality development, research elements and methods in related fields will become increasingly rich. In living circle scope delineation methods, issues exist such as difficult data acquisition, lack of relatively accurate or recognized division methods, and difficulty meeting China' s walking living circle construction needs. In construction level evaluation, residents' perceptions and needs are gradually receiving attention. As a complex of residents, facilities, and space, living circle construction level is influenced by multiple dimensions including residents' perception of facility services, objective facility construction conditions, and facility supply service accessibility, requiring comprehensive consideration and attention.

This study attempts to improve the accuracy of living circle scope delineation by proposing a method that merges walking planning spatiotemporal circles and Mapbox spatiotemporal circles to obtain residents' 15-minute walking activity space. Simultaneously, it incorporates public service facility accessibility and urban residents' satisfaction into living circle construction level measurement, constructing a bidirectional index system of facility layout and service evaluation that integrates objective construction and subjective perception, comprehensively analyzing living circle construction status. This provides theoretical and practical exploration cases for community living circle construction, improving resident satisfaction, and achieving efficient allocation of public resources.

1 Study Area Overview

Urumqi, the capital of Xinjiang Uygur Autonomous Region, is an important central city and transportation hub in northwest China. The administrative area covers 13,800 km^2, with a permanent population of 4.07 million and an urbanization rate of 96.1%. In 2021, the regional GDP reached 369.157 billion yuan, with secondary and tertiary industries accounting for 96.8% of the total. Urumqi is a typical arid region city, surrounded by mountains on three sides and built on the alluvial plain oasis of the Urumqi River. Population and industry are highly concentrated in the oasis area. The central urban area (Tianshan District, Xinshi District, Shayibake District, Shuimogou District, Toutunhe District, and Midong District) accounts for 82.42% of the city' s total population. Although the jurisdiction areas of peripheral Urumqi County and Dabancheng District are large, their population size and density are relatively small. The central urban area currently has 488 communities, accounting for 96.5% of the city' s total. Through Urumqi' s urban master plan and multi-spectral remote sensing imagery, the built-up area was identified as 338.65 km^2, covering nearly 4 million people. To better reflect community living circle construction, this study uses the overlapping area between Urumqi' s central urban area and built-up area as the research scope to reduce the impact of uninhabited desert regions on analysis results.

[Figure 1: see original paper] Schematic diagram of the study area

2.1 Data Sources

To understand the overall construction and layout of community living circle public service facilities in the study area, this study selected seven types of public service facilities as research objects based on domestic and international practices and research results regarding living circle public service facility types and classifications: health management, education, cultural activities, sports, commercial services, municipal facilities, and daily travel (Table 1). Python programs were used to crawl POI (Point of Interest) data from Amap to obtain facility spatial location information, resulting in 15,687 facility data points and 2,104 residential community data points. Considering the differences in service function coverage ranges among various facility types, the technical requirements of documents including the *Spatial Planning Guidance to Community Life Unit*, *Standard for Urban Residential Area Planning and Design*, and Xinjiang' s *Technical Standard for Construction of 15-Minute Urban Residents Activity Circle* were referenced as the basis for calculating coverage radii for different facility types (Table 1).

Walking planning data with high timeliness were used for living circle scope delineation. The walking planning function in Amap' s Web API was employed to calculate grid travel data, obtaining community walking routes in batch via HTTP/HTTPS format. To improve living circle boundary accuracy, this study used Mapbox spatiotemporal circles (https://www.mapbox.com/). Mapbox is

a global location data platform for mobile, Unity, and other platforms where users can customize maps. Python programs were used to batch obtain 15-minute walking spatiotemporal circles in geojson format.

For calculating per capita public service facility availability, WorldPop population distribution data were used, specifically the "China Population" 100 m precision grid dataset from https://hub.worldpop.org/, which offers certain resolution advantages. To improve data accuracy within urban areas, the seventh national census data for Urumqi's total population was used to correct the study area population. According to the seventh census, Urumqi' s permanent population is 4.0544 million. Using ArcMap software to clip the population raster yielded Urumqi' s population raster data with a calculated total of 4.1109 million. The raster calculator function in ArcMap was then used with the formula "raster × (4.0544/4.1109)" to standardize the city' s total raster population to 4.0544 million. Finally, the raster clipping function was applied again to obtain the community living circle population raster data for the study area.

Satisfaction represents a comprehensive measure of living circle service level. The 2021 Urumqi urban physical examination satisfaction survey investigated residents' satisfaction with urban construction across multiple modules including urban health and comfort, safety and resilience, and transportation convenience. To understand residents' satisfaction with the basic security capabilities of seven facility types including health management and education, corresponding facility satisfaction data were extracted from the survey results (Table 2). The questionnaire was conducted from September to October 2021, obtaining 2,104 valid responses from residents aged 18 and above who had lived locally for over six months, covering participants of different ages, occupations, and income levels, with spatial location information of participants' residences obtained.

[Figure 2: see original paper] Diagram of the living circle

2.2 Methods

2.2.1 Living Circle Spatial Delineation Method

The delineation of living circle spatial scope remains a technical challenge in current research and planning. Common walking living circle division methods include: (1) Travel range within a certain time. With the spread of 15/20-minute living circle concepts, this method is more widely applied. (2) Network spatiotemporal circles. Most websites with this function are in preliminary development stages, using road network base data that is not updated timely or does not provide batch acquisition methods. For example, Street Map based on OpenStreetMap geographic data can provide boundary-clear spatiotemporal circle vector data, but due to untimely domestic road network updates, the travel range timeliness is poor.

Based on existing research methods and China' s community living circle construction needs, this study selected walking planning spatiotemporal circles and

Mapbox spatiotemporal circles, using a merging approach to obtain 15-minute walking ranges with advantages in accuracy and timeliness, which can mitigate the impact of grid differences on walking spatiotemporal circle boundary accuracy and the timeliness issues of Mapbox spatiotemporal circle base road network data. The specific operation method involves using Arcpy to call ArcMap' s merge function for batch calculation of each community' s living circle scope. For a particular community, the Mapbox spatiotemporal circle and walking planning spatiotemporal circle are merged to obtain the 15-minute walking living circle.

Walking planning spatiotemporal circles derive from resident travel chains, primarily converting grids to polygon data. Using residential communities as origins and surrounding grid center points as destinations, Amap' s walking planning function obtains residents' walking times to surrounding grid center points. Grids within 15 minutes are then merged to obtain the spatial scope reachable within 15 minutes from the community, with each grid having time attribute data for surrounding communities walking to that location. Using Urumqi' s Tianran Ideal City community as an example, its 15-minute walking planning spatiotemporal circle is shown in Figure 2, where numbers on grids represent walking time from the community to that grid, with colors deepening as time increases.

The Mapbox platform provides customized maps for users and can batch obtain spatiotemporal circles for walking, cycling, and driving within certain time limits. Based on community coordinates, the website was accessed to obtain 15-minute walking spatiotemporal circles. These spatiotemporal circles have no internal attribute data, only spatial boundaries. After vectorization in geojson format, Mapbox spatiotemporal circle ranges can be obtained. Using Urumqi' s Tianran Ideal City as an example, its Mapbox 15-minute walking spatiotemporal circle vector is shown in Figure 15.

[Figure 15: see original paper] Mapbox 15-minute walking spatiotemporal circle

2.2.2 Construction Level Measurement Method

Measurement Index System Construction. Living circle construction level measurement includes not only objective facility construction conditions but also subjective service perception. Facility objective construction forms the service foundation, while residents' subjective perception provides direct feedback on service value. This study measures facility layout construction from facility layout and accessibility dimensions, and measures facility service evaluation from resident satisfaction (Table 3). Public service facility spatial layout is the main manifestation of living circle actual construction level, determining living circle service equity. Following Xinjiang' s *Technical Standard for Construction of 15-Minute Urban Residents Activity Circle*, facility point density reflects the aggregation degree of various facilities within living circles, while facility coverage rate reflects layout equilibrium. Facility accessibility within living circles

determines residents' public service enjoyment efficiency. This study uses the nearest distance from communities to a facility type and per capita availability of that facility type to measure public service accessibility. Nearest distance measures the difficulty of accessing the closest service, while per capita availability measures the average service quantity enjoyed by residents, reflecting service richness within living circles.

Measurement Method. To reduce the impact of subjectivity on measurement results, the objective entropy method was used for comprehensive calculation. After standardizing the 15 indicators of public service facility point density, facility coverage rate, nearest distance from residential points to facilities, per capita availability, and satisfaction proportion, information entropy was calculated based on indicator values to determine each indicator' s weight. Linear weighted summation was then used to obtain measurement results.

3.1 Community Living Circle Delineation Results

After merging 2,104 15-minute walking living circles in the study area, 468 15-minute living circles were obtained. Remote sensing imagery was used to identify urban land, yielding contiguous community living circles in Urumqi' s central urban area (Figure 3). Results show that community living circles cover 468.10 km^2, covering 82.42% of built-up area and serving 3.22 million people, accounting for 92.88% of built-up area population. This scope covers most of the built-up area and population. For 15-minute walking living circles, the average radius is 812.75 m and average area reaches 2.10 km^2, exceeding the minimum 1.3 km^2 living circle land scale in the *Standard for Urban Residential Area Planning and Design*. According to Xinjiang' s *Technical Standard for Construction of 15-Minute Urban Residents Activity Circle*, the recommended population for a living circle in cities with over 1 million people is 50,000-100,000. Currently, Urumqi' s 15-minute living circles serve an average population of 68,800, basically reaching the specified upper limit. Living circle service populations show obvious regional differences: 24.84% of living circles serve populations above 100,000, while 50.00% serve populations below 50,000.

[Figure 3: see original paper] Community living circles in the central districts of Urumqi City

3.2 Living Circle Construction Level Measurement

3.2.1 Overall Measurement

The point density, coverage rate, nearest distance, per capita availability, and satisfaction proportion of seven facility types in 468 15-minute living circles were calculated and substituted into the entropy method. Results indicate significant differences in construction levels among different facility types. Commercial service facilities show the best construction level with a score of 650.35, far exceeding other facility types. Health management, education, and daily travel

facilities are in the middle range with scores of 400-550. Cultural activities, sports, and municipal facilities perform poorly with scores of 200-350. This conclusion is consistent with Xiao Fengling et al.' s evaluation of public service facility spatial allocation in Urumqi.

For poorly performing facilities, the main issues are insufficient quantity and unbalanced layout, resulting in low point density, coverage rate, per capita availability, and nearest distance. In objective indicator measurement, point density and per capita availability values are generally high, while coverage rate and nearest distance are relatively low. Except for garbage transfer stations, point density and per capita availability of other public service facilities have greater impact on overall construction level than coverage rate and nearest distance. Among commercial service facilities, convenience stores, catering services, and logistics express facilities have coverage rates exceeding 85%, providing high service accessibility, especially catering service facilities with point density of 63.21 points $\cdot$ km^{-2}. Among health management facilities, health service centers (stations), clinics, and hospitals have coverage rates above 70%, while nursing homes have relatively low layout and satisfaction. Municipal facilities have the lowest construction level measurement values, mainly due to relatively low distribution density and per capita availability of police stations, garbage transfer stations, and fire stations. Daily travel public service facilities have much higher per capita availability scores than point density. Parking lots and bus stations score higher than rail transit. Poorly performing facilities are mostly basic security types, such as nursing homes in health management, junior high schools in education, parks and squares in sports facilities.

In resident satisfaction evaluation, results are similar to indicator measurement results. Commercial service facilities have the highest resident satisfaction at 78.65%, followed by health management, sports, and municipal facilities, while education and cultural activities have lower satisfaction.

3.2.2 Regional Differentiation Measurement

Urumqi' s living circle construction level shows spatial differentiation trends. Living circles in central urban areas have higher construction levels than peripheral areas, with obvious agglomeration in central areas of Tianshan District, Shuimogou District, and Midong District (Figure 4). Tianshan District, as Urumqi' s old urban area, has the most complete facility layout in the Xinhua North Road street area, showing the highest living circle construction level. Tianshan, Shuimogou, Shayibake, and Xinshi districts have significantly higher point densities than Midong and Toutunhe districts, indicating that facility layout quantity and distribution are concentrated in the four central urban districts (Table 4). From a spatial perspective, the junction areas of Tianshan, Shayibake, and Shuimogou districts have better living circle construction. The eastern Midong District shows obvious high-score living circle agglomeration, mainly because this area has a small population, and high per capita availability indicator scores at the district-level center with relatively concentrated

facilities lead to high total living circle scores. Catering facilities and parking lots (garages) account for relatively large proportions in overall measurement, and areas with denser distribution of these facilities at the district level have relatively higher living circle measurement scores.

[Figure 4: see original paper] Score proportion and score of indicator layer for public service facilities

3.2.3 Impact Differences of Different Facility Types on Living Circle Construction Level

Among health management public service facilities, clinics and hospitals have significantly higher impact on construction level measurement than health service centers (stations) and nursing homes. Education public service facilities show that junior high schools, primary schools, and kindergartens have significantly lower impact than nurseries. For cultural activity facilities, distribution density has a more prominent effect on construction level measurement than per capita availability, with cultural activity centers scoring far higher than cultural activity stations and cultural exhibition venues. Among sports facilities, gymnasiums (fields) and fitness centers score higher than parks and squares. Commercial service facilities have high distribution density and per capita availability but relatively low coverage rate and nearest distance. Among them, convenience stores have the lowest construction level, while parking lots (garages) have the highest. Municipal facilities have the lowest overall construction level, with garbage transfer stations being the lowest among them. In daily travel facilities, rail transit facilities are the main constraint on construction level.

[Figure 5: see original paper] Scores of living circles

4 Discussion

This study explored methods for community living circle scope delineation and construction level measurement, conducting empirical research in Urumqi. Results show that current living circle construction levels are unbalanced, with central areas significantly higher than peripheral areas—a phenomenon confirmed in case studies of Wuhan and Urumqi. Different public service facility types show varying construction levels and differential impacts on overall living circle construction level. In Wuhan' s case study, living circle construction level correlates with commercial service facility layout; areas with fewer commercial service facilities have lower resident consumption power, weaker driving effects on surrounding supporting facilities, and consequently affect the integrity of the living circle facility system—a conclusion similar to this study.

Methodologically, this study integrates Mapbox spatiotemporal circle data into walking planning spatiotemporal circles, reducing the impact of grid size differences on research area boundary accuracy during the spatialization of walking planning travel chains, while walking planning data compensates for the timeliness deficiencies of Mapbox spatiotemporal circle base road network data. Both

data types are relatively easy to obtain, yielding beneficial practice and reasonable results in the Urumqi case analysis. Since cities are shared spaces, residents' activity ranges may have dynamic changes and overlaps, potentially causing population calculation duplication during living circle delineation—a phenomenon also existing in case studies of Beijing' s central urban area and Xi' an' s central urban area. Future research on living circle service populations could consider further improving calculation methods to more accurately describe living circle service capacity from a population perspective, providing constructive suggestions for community living circle construction.

5 Conclusions

This study proposes a measurement logic from living circle spatial scope to comprehensive construction level evaluation. Based on big data including walking planning data and Mapbox, it obtains 15-minute living circle scope with good timeliness and accuracy by merging walking planning spatiotemporal circles and Mapbox spatiotemporal circles. It constructs a comprehensive evaluation system integrating objective construction and subjective resident perception based on facility spatial layout, accessibility, and resident satisfaction, providing technical method support for living circle construction in the study area. Using Urumqi' s central urban area as an empirical case, the study tested the operability and practical value of the living circle delineation method, obtaining the following results through measurement:

(1) The average radius of Urumqi' s 15-minute walking living circles is 812.75 m, with an average area of 2.10 km^2 and average service population of 68,800, meeting the requirements of the *Standard for Urban Residential Area Planning and Design* and Xinjiang' s *Technical Standard for Construction of 15-Minute Urban Residents Activity Circle*, representing a relatively appropriate living circle scope.

(2) Living circle construction level shows regional differentiation, with obvious agglomeration in central areas and old urban areas of each district. Central urban areas have higher construction levels than peripheral areas. Catering service facilities and parking lots (garages) are more densely distributed in urban district-level centers, resulting in relatively higher living circle measurement scores.

(3) Basic security function facility construction levels are relatively low. In health management, nursing homes and health service centers have lower construction levels than hospitals. In education, nurseries have higher construction levels than kindergartens, primary schools, and junior high schools that guarantee compulsory education. In sports facilities, parks and squares have lower construction levels than fitness centers. In commercial facilities, convenience stores have the lowest construction level. In municipal facilities, garbage transfer stations have the lowest construction level. In daily travel facilities, rail transit facilities are the main construc-

tion constraint.

(4) Point density and per capita availability measurement values are generally high, while coverage rate, nearest distance, and satisfaction are relatively low. Commercial service facility construction levels are higher than health management, education, and daily travel facilities, while cultural activity, sports, and municipal facility construction levels are lower, mainly caused by insufficient facility quantity and unbalanced layout.

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Note: Figure translations are in progress. See original paper for figures.