Research on the Delineation Method of Urban Community Living Circle Based on Transportation Network Analysis in Yuanping, China

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ARTICLE INFO	ABSTRACT
	In the context of accelerating global urbanization and the demands for high-quality and sustainable development, the exploration of an urban community living area delineation method based on traffic network analysis offers a fresh perspective for defining urban living areas. This paper employs a traffic network analysis method rooted in objective analysis. It leverages open-source big data on Points of Interest (POI) from public facilities and road network data obtained from relevant urban planning to construct a comprehensive road network dataset for the central urban area. Following the construction of the road network dataset, the paper conducts a service area and accessibility analysis of public facilities, which serves as an initial step in outlining the boundaries of the urban community living area. Subsequently, the delineation is further refined by considering factors such as development boundaries, as well as natural and man-made constraints such as rivers, railways, and major roads. The boundaries of the urban community living area undergo further adjustments, taking into account the scope of the development boundary and various constraining elements such as rivers, railways, and main roads. A final revision is made by considering subjective factors, where the boundaries of the ten-minute urban community living area are ultimately determined through extensive communication and coordination with various stakeholders. This approach is aimed at meeting the current societal development needs, which include breaking down segregation, fostering social interactions, strengthening neighbourly relationships, enhancing overall quality of life, promoting sustainable development, and creating a more humane and sustainable city. Its ultimate goal is to enable residents to feel a sense of belonging and happiness within the bustling urban environment.

1. Introduction

With the continuous acceleration of global urbanization and the continuous improvement of people's demand for quality of life [4], the separation of residential, commercial, industrial and other functional areas in traditional urban planning needs to be broken, and the non-negligible burden brought by urban expansion and resource waste to the environment and society in the past also

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needs to be adjusted immediately, so the concept of urban community living circle has received more and more attention and attention [1]. Urban community living circles create a more dynamic and inclusive urban society by integrating residential, commercial, and industrial functions in a closer area, encouraging cross-disciplinary interaction, enhancing neighbourhood relations, and improving community cohesion [20]. The establishment of urban community living circles, reducing commuting time and distance, not only reduces transportation costs, but also helps to reduce traffic congestion and environmental pollution, improve air quality, and thus improve the overall quality of life [14]. In addition, according to [10], urban community living circles help promote sustainable urban development, and by building intensive community living circles, resource allocation can be optimized, energy consumption and waste generation can be reduced [7]. At the same time, a more compact urban layout helps to protect the natural ecology, reduce the damage to farmland and natural landscapes, and lay the foundation for a sustainable future [8]. Therefore, the establishment of urban community living circles will break down segregation, enhance social interaction, improve quality of life, promote sustainable development, and create more humane and sustainable cities, allowing residents to find a sense of belonging and happiness in busy cities [2].

The concept of living circle originated in Japan, Japan in 1969 on the basis of the central location theory, put forward the theory of life circle composition and used in the planning of Japanese territory, wide area living circle, local living circle and settlement circle and other concepts were also proposed, of which "fixed living circle" refers to the space planning unit required for people's activity needs as the core, according to the daily life needs of residents, planning a day's life, providing a theoretical basis for the development of community living circle [5]. Later, the concept was accepted and gradually spread to other parts of Asia and countries such as South Korea [19]. After this concept spread to China, it has been continuously revised and refined, and the urban community living circle refers to the urban space divided into multiple community living circles based on the walking time of residents, and the principle that a 15-minute walk can meet the material and living cultural needs of residents [9].

At present, there are three hot spots in the research of urban community living circles, one is the research on community neighbourhood relations and community culture, such as [6] to study communities in urban planning from the perspective of racial injustice, which provides important planning methods for solving the problem of spatial equality [3].

In the study by [17], an analysis of interviews with 2003 respondents was conducted to explore the factors influencing social capital among the elderly in Japanese communities. Another area of focus is community development research, exemplified by Ryan's work [18], which examines the concept from the perspective of enhancing resilience. M. Reza Shirazi. [12] sought to establish principles for addressing a wide range of issues in communities, including environmental, physical, transport, social, psychological, economic, and political aspects. In a similar vein, [13,15] defined China's urban living circle by delving into temporal and spatial behaviour, drawing from a comprehensive analysis of urban living concepts both domestically and internationally. Meanwhile, [16] employed the convex hull method to delineate a one-hour living circle in Guangzhou based on the urban road transportation network. While prior research has extensively explored topics like community relations, cultural identity, community construction, and division, there remains a notable scarcity of studies focusing specifically on the partitioning of urban community living circles [11]. Therefore, from the perspective of the overall city, this study puts forward specific ideas on how to divide the living circle of urban communities in planning, promotes the spatial correspondence and unity of planning control units and social governance units, and guides the allocation of public service facilities in living circles at all levels.

2. Methodology

2.1 Scope of the Study

Yuanping, situated in Shanxi Province, China, stands as the pioneering pilot city in the delineation of urban living areas. This selection is attributed to its possession of relatively comprehensive foundational data and heightened public awareness and interest, making it an ideal choice for our research case. Yuanping City is located in the northern central part of Shanxi Province, bordered by the tourist resort Wutai Mountain in the east, Ningwu in the west, Xinzhou and Dingxiang in the south, and Daixian and Shuozhou in the north. According to the Urban and Rural Master Plan of Yuanping City (2018-2035), the 35.87 square kilometres of the downtown area of Yuanping was used as the research area (Figure 1).

Fig. 1. Area of research

2.2 Data Sources

The basic data of this study includes the current situation and planning data of the road network and public service facilities in Yuanping City.

2.2.1 Road network data

Three layers of railway, road centreline and river were extracted from the land planning map of "Controlling Detailed Planning of the Northern Area of the Yuanping City Centre", "Controlling Detailed Planning of the Southwest Area of the Yuanping City Centre", and "Controlling Detailed Planning of the Southeast Area of the Former Plain City Centre" in DWG format. In CAD, the road centreline is processed as an independent line segment with overlapping endpoints between each intersection, the road name and length information are extracted, and data tables such as motor vehicle speed limit, bus speed limit, and whether it is a one-way street line on each road are made according to the information provided by the traffic management department for backup.

2.2.2 Status and planning data of public service facilities

Through data mining technology, POI open-source big data is obtained by using the Application Programming Interface provided by Baidu platform to obtain point data of existing public facilities. The overall plan of Yuanping City and the detailed control plan are in the same vein, and various layers of public facilities and residential land are extracted from the general plan or control land planning map in DWG format.

2.3 Research Methods

Using the GIS software ArcGIS for simulation calculations, the urban community living circle was delineated by creating a traffic road network, constructing a city-wide road network dataset in the central urban area, and performing public service area and accessibility analysis (Figure 2).
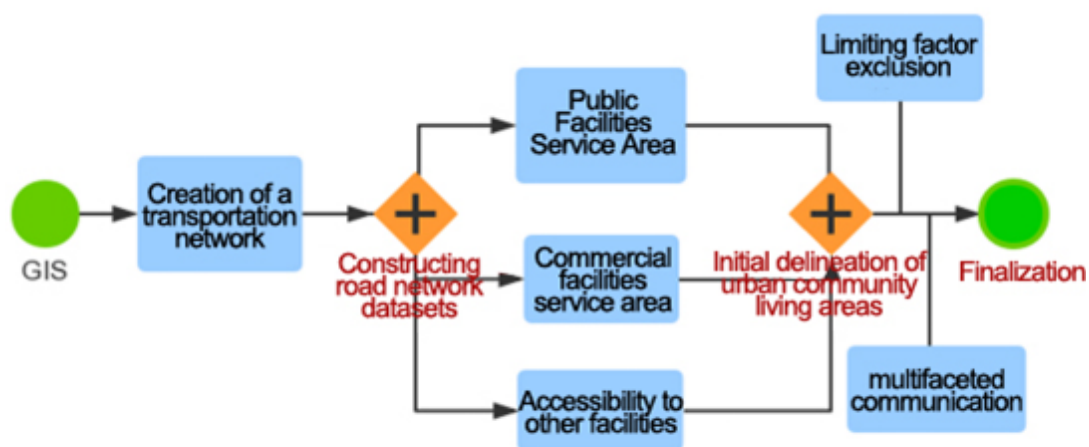

Fig. 2. Research framework

2.3.1 Network element preparation

The obtained road traffic information is processed into three types of features: edge feature sources (line feature classes), junction feature sources (point feature classes), and turn feature sources (turn feature classes). Among them, the source of edge elements includes railways, expressways, national highways, provincial highways, expressways, main roads, secondary roads, and branch roads, the junction feature source is a transit stop, turn feature sources are established special turn information.

2.3.2 Data combing

Use ArcGIS 10.3 to create a new road traffic feature dataset for downtown plains and import edge feature sources into the dataset. The geometric connectivity of road traffic data in the downtown area of the plain is processed with the dissolve tool, so that line features are connected only at coincident endpoints and are connected by multiple edges at coincident vertices (Figure 3). At the same time, the edge feature sources are divided into three connectivity groups, national highways, provincial highways, expressways, main roads, secondary roads, and branch roads are connectivity group 1, railways are connectivity group 2, and expressways are connectivity group 3. In addition, the data table of the road network of Yuanping City is loaded and linked, so that the name, length, driving

speed, public transportation speed, walking speed, and one-way line of each road are displayed in the data attribute table (Figure 3).
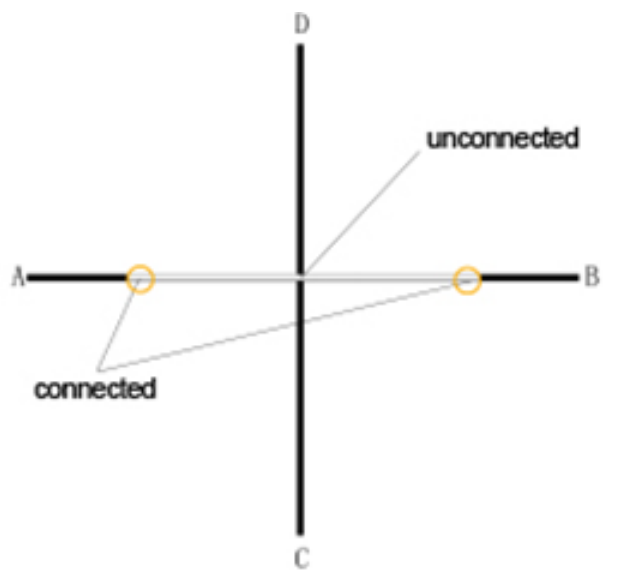

Fig. 3. Schematic diagram of road connectivity control

2.3.3 Build a network dataset

Select GeoDatabase as the workspace, check whether all the well-prepared network elements have been imported into the feature dataset, and add the driving time attribute, public transit time attribute, and walk time attribute to the network dataset after creating a new network dataset, building a turn model, setting connectivity, and selecting elevation fields. The specific method of setting the time attribute is to add a new attribute name definition, such as driving time, the usage type is cost, the unit is minutes, the value is [Shape Length]/ [driving speed]/1000*60, and the public transportation time and walking time are similar. From there, set up generic turns to ensure the integrity of the network dataset.

2.3.4 Accessibility analysis

Primary schools, hospitals, squares, parks to meet the needs of residents for medical treatment, leisure and recreation, commercial service industry facilities land enables residents to solve most of the life needs such as convenient shopping, breakfast, beauty salon and so on in a limited walking time, so the primary school service area analysis, hospitals, public space, commercial service facilities accessibility research, can be derived from the community life circle more rough scope. Therefore, on the basis of the complete construction of the transportation network in the downtown area of Yuanping, the service area and accessibility analysis of the public service facility land determined in the detailed control plan was carried out.

3. Results and Discussion

Primary and secondary schools are important urban public service facilities to meet the basic living needs of residents. Service areas are divided according to travel distance, and 300-meter and 500-meter service areas for primary and secondary schools are constructed (Figure 4) to provide reference for the division of urban community living circles.

Fig. 4. Accessibility analysis of primary and secondary schools

Hospital accessibility refers to the ability of residents within an area to communicate with relevant medical facilities in a variety of ways. As an important part of public service facilities, hospitals are an effective way to realize the equalization of regional medical services by dividing urban spatial units according to the analysis of accessibility from each residential point to the hospital, and then delimiting the boundaries of urban spatial units to reverse the newly configured medical facilities required by the community. Loading the planned residential land and hospital centre point, taking the residential area as the starting point and the hospital as the destination point for Origin Destination (OD) cost matrix analysis, according to the summary of the results of the first two questionnaires prepared by the general plan and control regulation, people often use driving and public transportation for medical treatment, and rarely use walking, so the accessibility data of the two modes of driving and public transportation are calculated separately, as the preliminary basis for the division of the urban community living circle in Yuanping City, and at the same time as an important parameter for the newly configured hospital in the community (Figure 5).
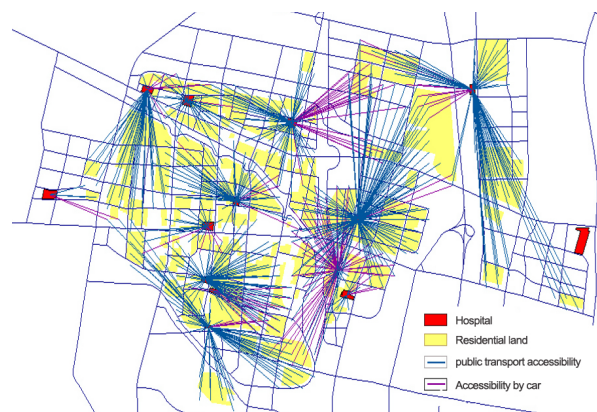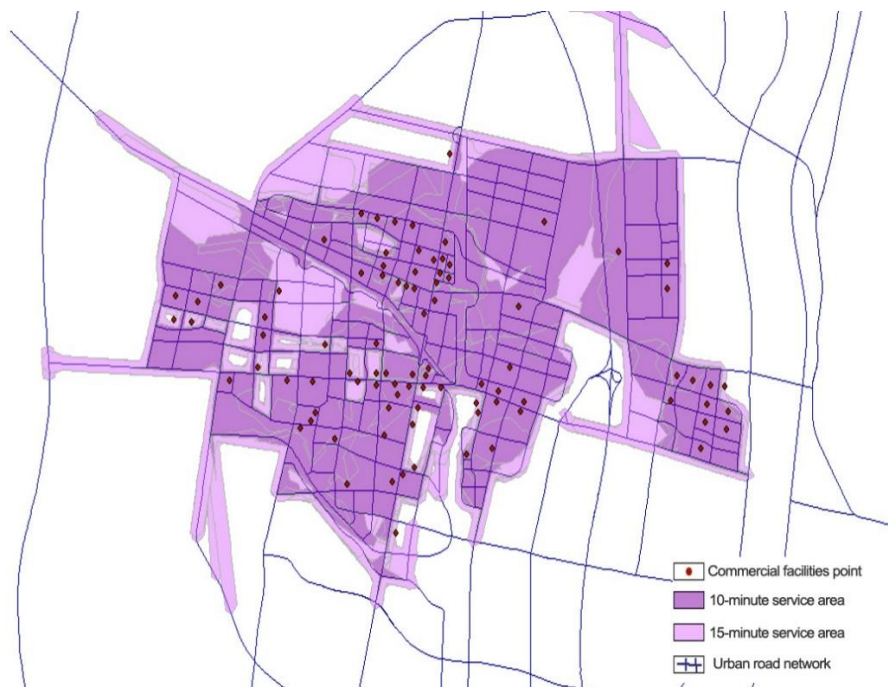

Fig. 5. Hospital accessibility analysis

The park is an important bearing space for residents' leisure and recreation needs, and it is also one of the indispensable contents in the composition of the community living circle. Therefore, taking the residential area as the starting point and the park and square as the destination, a special map of walking accessibility is made to meet the needs of people's daily public activities within a ten-minute walk, and form a preliminary basis for the division of community living circles at all levels in the downtown area of Yuanping (Figure 6).
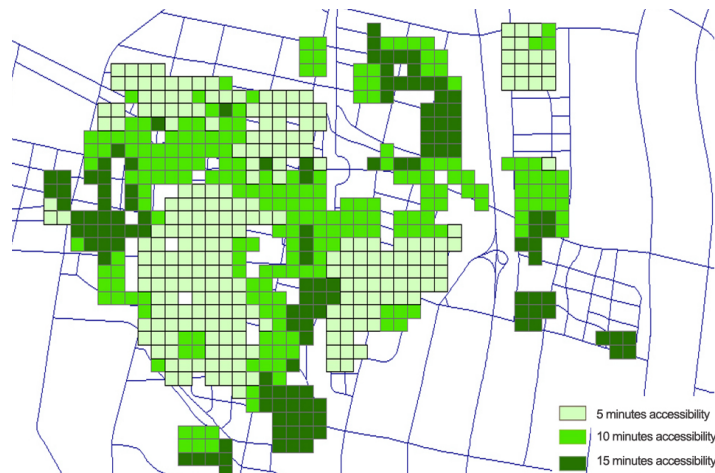
Fig. 6. Accessibility analysis of public space

Determine the central point of the land for commercial service facilities, using the commercial facilities determined by the control regulations as the centre, extract and construct a ten-minute walk service area, and provide a basis for the urban community living circle (Figure 7).


Fig. 7. Analysis of Service Areas of Facilities in Commercial Service Industry

The analysis of commercial service industry facility service area, primary school service area analysis, hospital accessibility analysis, and public space accessibility analysis were superimposed, and the urban community living circle was preliminarily divided according to the ten-minute walking distance, the ten-minute distance of hospital driving or public transportation (Figure 8).

Fig. 8. Community life circle division in ten minutes after traffic network analysis overlay

From the superposition analysis results, the urban community living circle basically formed a prototype, but the results under the Geographic Information System (GIS) analysis did not consider the linear factors of three-dimensionality, for example, from the plane point of view, the distance between the residential area and primary and secondary schools, hospitals and other facilities meets the ten-minute linear requirements, but from the three-dimensional level, the middle needs to cross rivers, railways and main roads with large traffic flow, from the perspective of safety and convenience, although it meets the walking distance, but does not meet the safety considerations. In order to ensure the safety of residents' daily shopping, medical treatment and education, the crossing of rivers, railways and main roads should be minimized, so on the basis of the preliminarily determined urban community living circle, the restrictive factors such as rivers, railways, and main roads should be eliminated (Figure 9), and the boundaries of urban community living circles should be corrected (Figure 10).
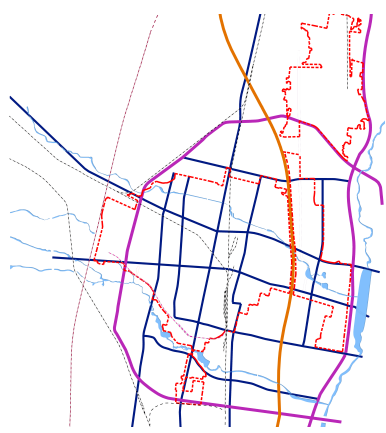
Fig. 9. Limiting factor
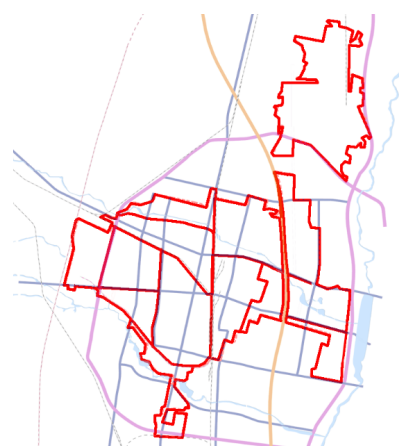
Fig. 10. The community life circle boundary after correction

The significance of this study lies in the fact that it is the smallest urban space unit for the revision of detailed planning within the scope of urban construction land, which combines the urban community living circle with the administrative jurisdiction of the community, adjusts the boundaries of the existing community office jurisdiction, and forms a unified planning control unit and social governance unit to facilitate planning preparation, implementation and urban governance. Therefore, it is necessary to fully communicate and coordinate with the local government, functional departments, neighbourhood offices, and residents, and determine the final boundary of the urban community living circle through repeated questionnaire surveys, opinion solicitation meetings, departmental coordination meetings, and symposiums (Figure 11).

Fig. 11. The final community life circle demarcation boundary

On this basis, in the end, the downtown area of Yuanping is divided into ten urban community living circles, with an average size of about 2-6 square kilometres, serving a permanent population of about 5,000-50,000. Each urban community living circle concentrates on building a public service system with complete facilities and perfect services, creating a dynamic street interface, and becoming a spatial organization model that guides the organic renewal and dynamic growth of the city. For the future construction of public facilities, urban community living circles should be equipped with primary schools, junior high schools, gymnasiums, street health service centres, nursing homes (including nursing homes for the disabled), nursing homes for the elderly, cultural activity centres (including youth and elderly activity centres), supermarkets, street-level commercial centres, bank business outlets concentration areas, express cargo distribution stations, independent parking lots, residential areas parks and other public service facilities, most of which should occupy independent land.

3. Conclusion

In the past, most studies of life circles have stopped analysing the impact of life circles or re-measuring the formed life circles. On the one hand, the starting point and foothold of the research are different, and on the other hand, it is also related to the limitations of the research data. The era of big data has brought good opportunities for refined and quantitative research on various urban problems, but the data source type structure it relies on is relatively single. Based on the above problems, this study uses the first-hand data obtained from projects such as "Urban and Rural Master Plan of Yuanping City (2018-2035)", "Controlled Detailed Planning of the Northern Area of Yuanping Central Urban Area", "Controlled Detailed Planning of the Southwest Area of Yuanping Central Urban Area", "Controlled Detailed Planning of the Southeast Area of Yuanping Central Urban Area", etc., and constructs network datasets and conducts transportation network analysis with POI open source

big data obtained by Baidu platform. To a large extent, improve the scientific and rationality of the division of community life circles.

First of all, the 10-minute walk service area of primary and secondary schools, the ten-minute walk area of public space, the pedestrian service area of commercial service facilities, and the ten-minute walkable area of hospital driving, or public transportation are superimposed to outline the general boundary of the urban community life circle. Then, the restrictive factors such as rivers, railways, and trunk roads are eliminated, the boundaries of the urban community living circle are revised according to the scope of the development boundary, and the boundaries of the urban community living circle are finally determined after full communication and coordination with all parties. The urban community living circle is not only a convenient service circle, but also a community administrative jurisdiction, promoting the spatial correspondence and unification of planning control units and social governance units, and providing a basis for the future allocation of public service facilities.

From the experience of Yuanping City, China, the boundary of urban living circle basically conforms to the actual situation of Yuanping City, and has also been recognized by many parties, which proves the scientific and rational research of the division of living circles at all levels of the city based on transportation network analysis, and the method can make a certain range of promotion attempts, and can provide a good basis and support for the allocation of urban public service facilities in the planning process.

Acknowledgement

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