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Article

Correlation Study on 15-Minute Urban Living Circle Accessibility and Residents' Well-Being Using Multi-Source Spatiotemporal Data

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Abstract: This study utilized publicly available multi-source spatiotemporal data to analyze the relationship between the accessibility of the 15-minute urban living circle and residents' well-being. Taking a high-density urban area in Shanghai as an example, the data sources included GIS data, point-of-interest data, transportation network data, public transportation station data, demographic information, and publicly available well-being proxy indicators. Through network-based travel time calculation and standardized accessibility index, the accessibility of education, healthcare, commercial facilities, and green spaces was measured at the community level, and these indicators were further compared and analyzed with community-level well-being proxy variables, while considering some social demographic control variables. The results showed that there were significant differences among different facility types and different communities. Among them, the overall accessibility of commercial and service facilities was relatively high, while the spatial distribution of green spaces was more uneven. The regression analysis results also indicated that in this study area, the correlations between green space and healthcare accessibility and well-being proxy indicators were relatively stronger, while the correlations between education and commercial facilities were weaker. However, these results should be regarded as statistical correlations rather than causal explanations. This study provides a method for connecting objective accessibility measures with public well-being indicators at the community scale, which can be used to identify potential service gaps and provide references for the optimal allocation of resources within the 15-minute living circle.

Keywords: 15-minute city; urban accessibility; residents' well-being proxy; public multi-source spatiotemporal data; GIS analysis

1. Introduction

1.1. Research Background

The concept of "15-minute city" has been frequently discussed in urban planning debates in recent years. The core idea is to enable residents to reach educational, medical, commercial facilities, and green spaces for daily services within approximately 15 minutes by walking, cycling, or using public transportation [1]. Compared to the planning approach in the past that was more inclined towards large-scale infrastructure construction, this framework places greater emphasis on spatial accessibility at the community level and the satisfaction of daily needs [2].

With the gradual enrichment of GIS, point-of-interest data, open road networks, public transportation data, and urban statistical information, it is now possible to depict the accessibility situation of different areas in greater detail. These data can be used to describe the spatial distribution of facilities, the degree of traffic connectivity, and the time required to reach different service points [3].

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However, accessibility is not merely a spatial measurement; it may also be related to residents' perception of convenience, community satisfaction, and overall happiness experience [4]. In the absence of individual-level survey data, public happiness-related indicators are often used as alternative variables at the community level.

1.2. Research Motivation

Most current studies focus on aspects such as service coverage, spatial equity, and transportation accessibility in 15-minute cities. These studies are mainly used to determine whether residents can reach key public service facilities within a reasonable time frame [5]. However, from the existing literature, the discussion on the connection between the objective accessibility and the subjective well-being of residents is still relatively limited. In some communities, even if the facilities are close, residents may still feel inconvenience due to differences in service quality, inconvenient travel routes, traffic congestion, or individual needs.

Moreover, many accessibility studies still use relatively static indicators, such as facility density or straight-line distance. These methods are simple to calculate, but often fail to reflect the actual travel conditions under the real transportation network. Therefore, this paper combines publicly available multi-source spatiotemporal data to analyze the relationship between the accessibility of the 15-minute living circle and the proxy indicators of community-level well-being in a specific urban context [6].

1.3. Research Objectives

This study, based on publicly available data, analyzes the relationship between the accessibility of a 15-minute urban living circle and the proxy indicators of community well-being. The main content focuses on the assessment of accessibility of education, healthcare, commercial facilities, and green spaces, spatial differences among different communities, as well as the correlations between these accessibility indicators and related proxy indicators of well-being. On this basis, it discusses the meaning of community service provision at the planning level.

In this study, accessibility is understood within the context of the combined effects of social, economic and environmental conditions. As the analysis relies on publicly available data and proxy indicators, the results are more appropriately regarded as correlations at the community level.

1.4. Case Study Context

A high-density urban community in Shanghai was selected as the research object. This area includes residential communities, schools, clinics, hospitals, commercial facilities, parks, and public transportation stations. The overall spatial structure is compact and the degree of land use mixture is relatively high. Therefore, it is suitable for observing the accessibility characteristics within the 15-minute living circle framework.

In terms of methodology, the neighborhood scale is used as the spatial unit, and GIS data, points of interest (POI), transportation networks, public transportation stations, as well as population and socio-economic data are combined to calculate accessibility, with control variables also being introduced. At the same time, publicly available proxy indicators, such as life satisfaction, community satisfaction, and indicators related to neighborhood livability, are used to depict the well-being status at the community level. Through this case, this paper focuses on whether there is a correlation between the convenience of accessing daily services and the level of neighborhood well-being in high-density urban environments.

2. Literature Review

2.1. 15-Minute City and Urban Accessibility

The core of the 15-minute city urban planning concept is to meet residents' needs for accessing basic public services within a relatively short travel time [7]. The related services usually include education, healthcare, commercial facilities, public transportation, green spaces, and community service facilities. Compared with the traditional planning approach that focuses more on the overall functional layout of the city, the 15-minute city pays more attention to the accessibility at the neighborhood scale and the daily activity needs of residents [8].

In accessibility studies, common approaches involve measuring using indicators such as walking distance, network travel time, service coverage, and facility density [9]. Among these, travel time calculations based on road networks and isochrone analysis are widely used to determine whether a specific service can be reached within a 15-minute range [10]. Additionally, some studies employ cumulative opportunity indicators, which reflect the level of service supply by counting the number of accessible facilities within a specific time threshold.

However, many studies still adopt relatively static measurement methods, often assuming that residents have similar travel speeds, route choices, and behavioral preferences. The reality is much more complex, as accessibility is influenced by factors such as time, transportation methods, age structure, and community environment [11]. Even though some facilities are relatively close, their actual accessibility may not be convenient due to factors such as traffic congestion, restricted walking environment, or poor traffic conditions. Therefore, merely considering the spatial distribution of facilities is often insufficient; it is necessary to conduct analysis in combination with real travel conditions.

2.2. Multi-Source Spatiotemporal Data in Urban Studies

Multisource spatiotemporal data are widely applied in urban research. GIS data provide information such as boundaries, road networks, land use, and community units; POI data describe the locations and types of urban services; traffic data estimate travel times for walking, cycling, driving, or public transportation. Open mobility, public transportation, and urban statistics can reflect traffic connectivity, service accessibility, and accessibility during different time periods [12].

If these data are examined together, it can be observed that each of them is actually answering a different question. POI is more like saying "what is there", the transportation network answers "can it be reached", while mobility or public transportation data is closer to "how it is actually done". Using any single type of data alone would be rather limited. Therefore, many current studies combine these data to better understand the concept of accessibility. After doing this, the analysis is no longer simply a matter of counting the number of facilities, but rather focuses more on the difference between spatial opportunities and actual travel [13].

There are differences in scale, update frequency, coordinate system, and precision between the data. Some public data may also have missing values or inconsistent measurement standards. Additionally, approaches like proxy indicators are essentially a compromise solution, which to some extent loses the detailed information at the individual level. Thus, in the result interpretation, these limitations should not be fully regarded as precise conditions.

2.3. Accessibility and Well-Being

Well-being is influenced by many factors, including income, health condition, environmental quality, and whether it is convenient to access services on a regular basis. Generally speaking, if services are more accessible, such as hospitals or some daily facilities being located nearby, going out will be easier, the time spent on the road will be shorter, and there will be more choices in life [14]. For example, when hospitals are close, the journey to and from the hospital won't be so troublesome. If there are green spaces nearby, sometimes people are more willing to go out for a walk, and there may not be a particularly clear purpose.

High accessibility does not mean a good experience. Some places, although close in facilities, might be crowded, or have higher prices, less stable services, and may not be as convenient as imagined when actually used. Even if the surrounding conditions are average, some residents might still find their lives quite satisfactory. Accessibility here is merely a background.

Many current studies are actually somewhat similar in their approach. They separate accessibility and well-being and use a more static method. They often focus on only one type of service, such as healthcare or transportation. This fragmented approach makes the analysis rather scattered. Therefore, to be more comprehensive, it might be necessary to combine different data, such as GIS, POI, transportation data, population structure information, and some well-being-related indicators, and view them together within a framework to examine the situation of the 15-minute living circle and its relationship with community-level well-being [15].

3. Data and Methodology

3.1. Data Collection

This study utilized publicly available multi-source urban data to assess the accessibility of the 15-minute urban living circle and further observe its relationship with indicators of residents' well-being. The involved data mainly included road networks, walking and cycling paths, public transportation stations, POI facilities, green space data, as well as spatial information such as administrative or neighborhood boundaries.

The data on interest points and facilities mainly comes from OpenStreetMap (OSM) and the municipal public data open platform of Shanghai. It covers categories such as education, healthcare, commercial services, and green spaces. During the actual processing, these facilities will be uniformly organized and classified into four categories for analysis.

The transportation network data also comes from OSM and related public transportation datasets, including road connection relationships, walking and cycling routes, and public transportation lines, which are used for the subsequent calculation of travel times.

The administrative boundaries and neighborhood unit data are sourced from OSM and the Shanghai Open Platform, and are used for spatial unit division and aggregation analysis.

The population density and social economic variables are mainly derived from public statistical yearbooks and district-level or street-level population census data, which are used to depict the basic demographic and social background situations.

In the absence of more detailed survey data, indicators related to well-being are approximated by using public statistics or proxy variables from survey results, such as indicators of regional life satisfaction or community satisfaction, to represent the well-being situation at the community level.

All the data were spatially aligned and uniformly processed before use, and finally converted to the neighborhood scale for subsequent accessibility calculations and correlation analyses.

3.2. Data Preprocessing

All the data were cleaned, standardized and spatially aligned before being used. The POI and facility data were first checked for duplicates and then reorganized and classified into four categories: education, healthcare, business and green space. The transportation network data mainly involved repairing some broken sections, and the pedestrian and bicycle networks were distinguished from the motor vehicle roads. The public transportation stations were also connected to the pedestrian network, and corresponding speed parameters were set according to different travel modes. The population and socio-economic data were uniformly aggregated to the neighborhood units to ensure consistency with the spatial boundaries. The proxy indicators related to health and well-being are also matched or aggregated at the neighborhood scale, so that they can be compared with the accessibility indicators within the same spatial unit.

All spatial data are ultimately projected into a unified coordinate system and integrated and processed at the neighborhood level, thus ensuring the comparability between the subsequent accessibility indicators and the proxy indicators of well-being.

3.3. Accessibility Metrics

A 15-minute living circle usually refers to the spatial range that can be reached within approximately 15 minutes by walking, cycling or using public transportation from the central point of a community. Within this range, the accessibility indicators are mainly characterized from several perspectives. One is the Cumulative Opportunity Index, which is used to count the number of facilities that can be reached within the 15-minute travel time; another is the Nearest-service Travel Time, which represents the shortest time required to reach the nearest related facility; and there is the Weighted Accessibility Index, which takes into account factors such as distance and facility availability to a certain extent.

These indicators will be calculated separately for different service types and different travel modes, and will be used to reflect the actual travel situation within the community and in a certain surrounding area.

3.4. Well-Being Indicators

The well-being of residents is mainly reflected through publicly available proxy indicators at the community level, such as life satisfaction, community satisfaction, and some comprehensive indicators related to livability. The specific indicator used depends on the availability of data. These indicators will be matched or aggregated to spatial units at the community level to be consistent with accessibility indicators. Since this study did not use individual questionnaire data, the well-being indicators are more inclined to reflect the overall situation of the community rather than the subjective feelings of individuals. The control variables include basic social demographic characteristics such as age structure, income level, education level, employment status, and population density. In the analysis, accessibility is more treated as a type of factor that may affect the well-being of the community.

3.5. Methodological Framework

The analysis procedure used the techniques of GIS, network analysis, and statistical modeling. GIS mainly integrated spatial data such as residential areas, service facilities, and community boundaries. The network analysis part was based on real roads and transportation networks to estimate travel times. For different service and travel, a 15-minute reachable range was calculated separately, which was the foundation for calculations of accessibility indicators.

The statistical analysis mainly focuses on whether there is a relatively obvious relationship between accessibility and the welfare proxy indicators at the neighborhood level. Some simple descriptive comparisons were first conducted to see how significant the differences in accessibility were among different neighborhoods. Then, correlation analysis was used to examine the connection between the two. In the regression model, accessibility was regarded as the main explanatory variable, and some social demographic control variables were also added. If there is a spatial aggregation effect, spatial regression will be employed for handling. In general, this study is more inclined to describe this statistical relationship.

4. Case Study and Analysis

4.1. Study Area and Sample Description

This study selected a high-density urban neighborhood in Shanghai (located in Huangpu District and mainly covering selected parts of Ruijin Second Road, Dapuqiao, and Wuliqiao subdistricts; these official subdistricts were chosen because they represent a compact inner-city environment with dense residential population, mixed land use, diverse daily-service facilities, and relatively complete walking and public transport networks; the 32 neighborhood units refer to analytical spatial units, which were delineated by overlaying public community boundaries, residential-block distribution, and major road barriers, rather than directly using official neighborhood committee units) as a case study.

The research area was further divided into 32 analytical neighborhood units based on the public administrative boundaries and the distribution of residential spaces. During the subsequent calculations, each neighborhood would have a population-weighted residential center point, which would represent the approximate activity location of the residents.

The data used in the research mainly came from OpenStreetMap and the Shanghai Public Data Open Platform, including information on POI facilities, road and pedestrian networks, green spaces, and public transportation stations. Population density and socio-economic variables were compiled from public statistical yearbooks and census data. These data came from different sources, meaning that the original formats and scales were not completely consistent. Therefore, before analysis, they were uniformly organized and summarized to the same community scale.

The part related to residents' well-being did not use individual questionnaire data. Instead, publicly available community-level indicators were used to approximately reflect this aspect, such as life satisfaction, community satisfaction, and similar community evaluation indicators. Considering the need for subsequent comparison with accessibility results, these indicators were also uniformly processed at the neighborhood scale.

In terms of the spatial distribution, commercial facilities and transportation hubs are mostly located around major roads and rail transit stations. The distribution of green spaces and medical facilities shows more significant differences. Some neighborhoods can easily access the necessary services, while in other areas there are certain gaps.

4.2. Accessibility Mapping

Accessibility is calculated for four types of services: education, healthcare, commerce, and green spaces. On a community basis, the walking, cycling, and public transportation networks are incorporated into the same framework, and the number of accessible facilities within a 15-minute travel range is counted. The cumulative opportunity index is then standardized on a 0 to 1 scale to ensure comparability among different service types. Table 1 reports the descriptive statistics for 32 communities.

Table 1. Accessibility Indicators by Service Type

Service Type	Mean Accessibility Index	Standard Deviation	Minimum	Maximum
Education	0.63	0.18	0.28	0.91
Healthcare	0.58	0.16	0.31	0.86
Commerce	0.71	0.20	0.34	0.96
Green Space	0.49	0.22	0.17	0.88

As can be seen from Table 1, there are significant differences in the accessibility of different types of services. The accessibility of commercial facilities is the highest overall, indicating that most community residents can access basic retail and daily services within a 15-minute radius. The situation for educational facilities is also relatively similar, which is related to the wide distribution of schools around residential areas. In contrast, the accessibility of medical services is at the middle level, and the differences between communities are not too significant. The situation of green spaces is different, with overall accessibility being relatively low, and the gap between communities is also more obvious.

Figure 1 further illustrates the distribution of different service types across communities. Commercial facilities are generally at a higher level, while the accessibility of green spaces is generally low and has a wider fluctuation range. Education and medical services are roughly in between. From the comparison of communities, different service resources do not show completely consistent spatial distribution characteristics. Some communities with concentrated commercial facilities may not have the same advantages in terms of green space or medical resources. This means that when discussing the 15-minute living circle, one cannot solely rely on the performance of a certain service to judge the overall accessibility situation. Different service types still need to be examined separately.

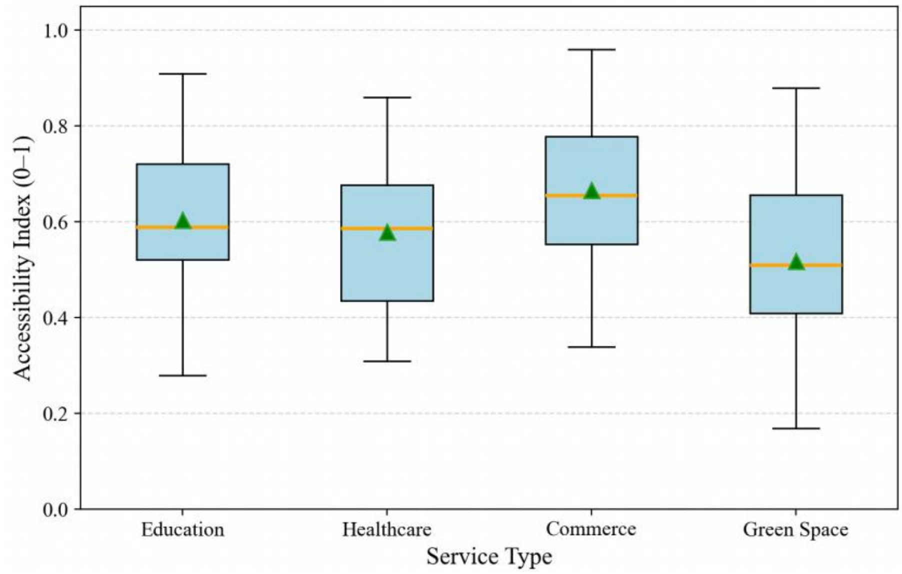

Figure 1. Distribution of 15-Minute Living Circle Accessibility by Service Type

4.3. Correlation Analysis

The subsequent analysis mainly focuses on the relationship between accessibility and community-level well-being indicators. The well-being data used here are derived from public surveys or statistical data, reflecting the overall situation of the community. Figure 2 shows the corresponding relationship between the two. Each point represents a community. The horizontal axis represents the standardized accessibility index, and the vertical axis represents the proxy indicator of well-being. The trend line in the figure can help observe whether there is a significant trend in both, and whether this relationship remains consistent across different communities.

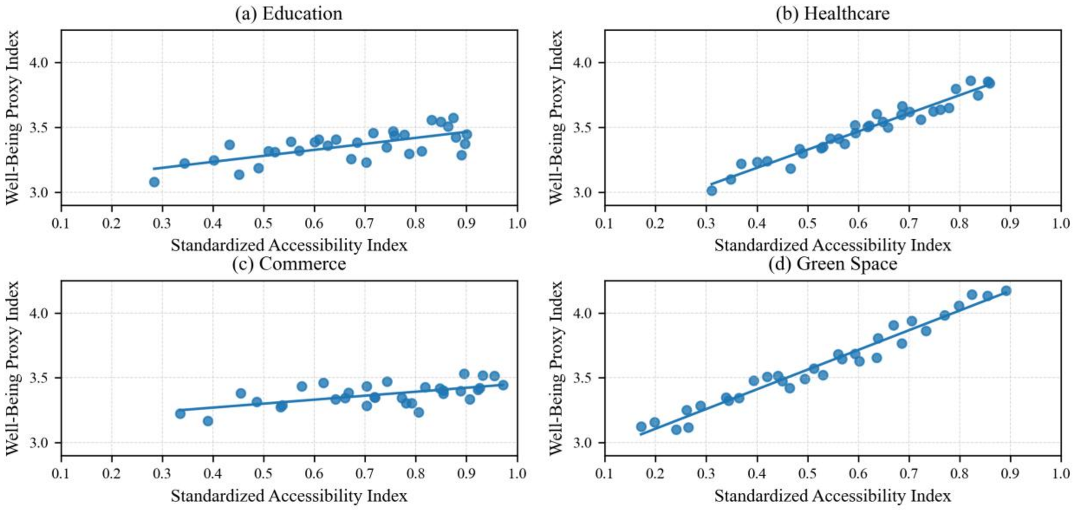

Figure 2. Accessibility–Well-Being Proxy Scatterplots for Four Service Types

In the scatter plot, it can be observed that the points corresponding to green space and medical accessibility are relatively more concentrated, and there is a certain clustering phenomenon within the range of higher welfare proxy indicators. The distribution of commercial accessibility is relatively scattered, and the corresponding relationship between it and the welfare indicators is not stable. The overall change range of educational accessibility is relatively small, and most samples are concentrated in the middle range.

The regression results are presented in Table 2. Model 1 only includes accessibility variables, Model 2 incorporates socio-demographic control variables, and Model 3 further considers the population density factor.

Table 2. Regression Results for Accessibility and Neighborhood-Level Well-Being Proxy Indicator

Variable	**Model 1 Coefficient**	**Model 2 Coefficient**	**Model 3 Coefficient**
Education Accessibility	0.071	0.052	0.046
Healthcare Accessibility	0.184*	0.163*	0.151*
Commerce Accessibility	0.063	0.041	0.038
Green Space Accessibility	0.236**	0.211**	0.198**
Average Household Income	—	0.176*	0.162*
Proportion of Elderly Residents	—	-0.058	-0.064
Education Level	—	0.097	0.088
Population Density	—	—	-0.112
R^2	0.312	0.438	0.467
Adjusted R^2	0.214	0.336	0.349

Note: * $p < 0.05$, ** $p < 0.01$.

Accessibility to healthcare and green spaces generally showed a positive correlation across all three models, with a consistent overall trend. The coefficient for green spaces was relatively higher and remained stable across the models. Healthcare accessibility remains consistent even after adding control variables, indicating a stable relationship between it and greater security or a better living environment.

The coefficients for the accessibility of education and business are generally positive, but they are not statistically stable. Their performance varies little across different models, but they cannot be simply classified as irrelevant either. Rather, it is more likely that their effects are relatively localized. For instance, education has a greater impact on families with school-aged children, while commercial services are already relatively well-established in most communities.

From Model 1 to Model 3, the R^2 value gradually increases, indicating that only accessibility variables cannot adequately explain the differences in community-level well-being. The inclusion of social demographic factors and community density will provide supplementary explanations to the overall explanatory power.

4.4. Scenario Simulation

Five communities with green space accessibility below 0.30 were selected for a simple adjustment test. Two main changes were made: first, two pocket parks were added near residential areas; second, the connectivity between existing parks and surrounding walking paths was optimized.

After the adjustments, the green space accessibility index of these communities improved from 0.24 to 0.39. Comparing this to the coefficients in Model 3 in Table 2, incorporating this change into the estimation framework would result in a certain degree of improvement in the community-level welfare agency index, but the magnitude is not significant. This result is merely a scenario extrapolation based on model coefficients.

Overall, there are still significant differences in accessibility between different service types and different communities. Commercial and educational levels are relatively high overall, while the distribution of green space varies more. The regression results show a relatively stronger correlation between healthcare and green space with the welfare agency index, while the correlation is relatively weaker with education and commerce. Since the data mainly comes from publicly available geographic information and statistical data, these conclusions are more suitable for understanding as community-level correlations rather than direct results from individual surveys.

5. Discussion

5.1. Interpretation of Results

The case study shows the 15-minute living circle vary among different service types and communities. The central areas generally have better accessibility to commercial and educational services. The distribution of green spaces is less uniform, and it is more pronounced in some peripheral communities. The spatial distribution of medical services is relatively more even. When these factors are considered together, they more reflect the spatial imbalance of urban services themselves and the influence of the transportation network in the actual accessibility process.

Regression and correlation results show a relatively stable relationship between green space and healthcare accessibility and community-level welfare proxy indicators, while the relationship is weaker for education and commerce. This result remains consistent across different models, showing little directional shift. This may be related to the fact that green spaces and healthcare are more closely integrated into daily life experiences, such as leisure spaces and basic health services. Differences between communities remain significant. Even with similar accessibility levels, the final welfare proxy indicators may differ, influenced by factors such as income structure, population density, environmental conditions, and social relationships. Therefore, accessibility is only one relevant factor here.

5.2. Policy Implications

These accessibility disparities offer some direct insights for planning. In communities lacking green space, prioritizing the addition of small-scale open spaces, such as pocket parks or small recreational areas, and connecting these spaces with existing parks via pedestrian paths, is more realistic. A similar situation exists in healthcare; in communities with fewer clinics and longer travel times, increasing the coverage of basic medical services, especially in areas with high concentrations of elderly people, is advisable. While commerce and education are generally relatively accessible, optimizing spatial layout and transportation connectivity in some peripheral areas can still alleviate imbalances.

On a larger scale, these results demonstrate the significance of considering the accessibility of multiple services simultaneously in community planning. In practice, accessibility indicators can be combined with population structure and socioeconomic information to roughly determine which areas require priority resource investment. Rather than simply looking at the quantity of facilities, it's more important to consider whether these facilities are truly easy to reach on foot, by bicycle, or by public transportation. Furthermore, differences in travel patterns at different times and among different groups must be taken into account, as neighborhood travel patterns derived from publicly available data are inherently influenced by time and group differences.

5.3. Limitations and Future Work

This study also has some obvious limitations. The well-being indicators used are aggregated public proxy data at the community level, which may not accurately reflect individuals' subjective feelings, especially short-term emotional changes. The data is mainly cross-sectional information, including accessibility, public transportation, and statistical variables, lacking the temporal dimension of daily changes or seasonal fluctuations.

Current results only demonstrate a statistical relationship between variables. Future research, if feasible, could incorporate longer-term travel data and repeatedly measured well-being indicators to better understand why different communities react differently to similar accessibility conditions. Combining objective accessibility indicators with participatory mapping data and real-time public data could also supplement our understanding of actual experiences. Furthermore, comparisons between different cities could be helpful in determining the generalizability of this pattern.

These results primarily indicate a correlation between accessibility and community-level well-being proxy indicators, but this relationship is not determined by a single factor and is also influenced by social and environmental conditions. Based on this analysis, targeted optimization of green spaces and medical resources could potentially improve the overall livability of communities.

6. Conclusion

This study analyzes the relationship between accessibility within a 15-minute urban living circle and community-level welfare agency indicators based on publicly available multi-source spatiotemporal data. The data integrates GIS, POI, transportation networks, public transportation stations, demographics, and welfare agency indicators to construct a community-scale framework for measuring the accessibility of education, healthcare, commerce, and green spaces.

Taking a high-density urban area in Shanghai as a case study, significant differences in accessibility exist between different service types and communities. Commerce and education generally have high accessibility, while green spaces show greater variation and uneven distribution across different communities. Healthcare accessibility is at a moderate level, but spatial gaps or discontinuities are still visible. In correlation and regression analyses, the relationships between green spaces and healthcare with welfare agency indicators are relatively stable, while those with education and commerce are weaker. These results are better understood as statistical associations rather than causal relationships.

A core aspect of this study is placing accessibility and community-level welfare indicators within the same 15-minute living circle framework, rather than focusing solely on facility distribution. In addition to using GIS for spatial analysis and network travel time calculation, publicly available proxy data was also introduced, allowing the analysis to simultaneously cover "spatial accessibility" and "community status".

From a planning perspective, simply increasing the number of facilities may not solve all problems; the key is whether these facilities are truly accessible under actual travel conditions. Green spaces, medical services, and connectivity for walking, cycling, and public transportation still have room for improvement in some areas. Resource allocation may need to focus more on areas with insufficient accessibility and overlapping high-density residential areas.

Future research could consider incorporating public data with longer time horizons to see if changes in accessibility are accompanied by changes in proxy indicators of community well-being. Simultaneously, more environmentally relevant factors, such as air quality, noise, street safety, and thermal environment, could be included to provide a more comprehensive understanding of urban quality of life. Furthermore, comparisons between different cities may help determine whether these relationships are consistent across different urban structures.

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