Analysis of public transport accessibility in the Main Urban Area of Zhengzhou Based on Baidu Map API

Xuegang Liang, Yanfang Jin, Chengming Zhu*

College of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo, Henan, 450001, China

(*zhuchengming@hpu.edu.cn)

Abstract. With the rapid development of China's economy and society and the acceleration of urbanization, major cities are experiencing an unprecedented test of public transport. This study uses the open network data provided by Baidu map API, focuses on the key node of Zhengzhou railway station, radiates to the main urban area of Zhengzhou, and deeply analyzes the space, time and economic accessibility under the two common travel modes of driving and bus. The results show that in the inner area of the third ring road in Zhengzhou, due to its superior geographical location and developed transportation network, the accessibility is high, but Huiji district has poor accessibility due to its remote location and unbalanced traffic layout. Taking Zhengzhou railway station as the starting point, the driving mode covers a wide area of the main city in one hour. Although the bus can be reached within 2 hours, the specific area in the north takes a long time, which highlights the urgency of bus route optimization. Compared with driving, the cost of bus travel is very low, only 5 yuan can reach most areas of the main city, but some areas need to be optimized to balance traffic and improve the overall travel efficiency. The overall performance of public transportation in Zhengzhou city is good in terms of coverage, efficiency and cost, but it is necessary to improve the accessibility of specific areas in order to establish a more balanced and efficient transportation network.

Keywords: Baidu map API, public transport, accessibility, Zhengzhou City

1 INTRODUCTION

In the process of rapid urbanization, China's major cities are facing public transport challenges. Among them, Zhengzhou, as the transportation hub and economic center of the Central Plains, the operation of public transportation system is very important. With the expansion of urban scale, the rise of population density and the surge of motor vehicles, Zhengzhou's public transportation is under great pressure. Problems such as morning and evening peak congestion, prolonged waiting time, and declining service quality affect the public's travel experience and restrict sustainable development. It is of practical significance to conduct an in-depth analysis of the accessibility of Zhengzhou public transport system. Evaluate the coverage, convenience and service level, provide

G. Chen et al. (eds.), *Proceedings of the 2024 International Conference on Rail Transit and Transportation (ICRTT 2024)*, Advances in Engineering Research 254,
https://doi.org/10.2991/978-94-6463-610-9_5

scientific basis for planners, optimize the layout of lines, stations and transfer hubs, and improve efficiency. It is of strategic value to enhance the attractiveness of public transport, reduce the use of private cars, alleviate congestion, reduce pollution and promote green travel.

Accessibility research is a key area in urban planning and transportation system optimization. Many researchers use different methods and techniques to assess the impact of transportation systems. Lucas Albuquerque-Oliveira J. et al.[1] proposed a route-based accessibility index, which provides a way to comprehensively evaluate the impact of transportation routes on the access opportunities of people within their service scope. By considering the average accessibility level provided by each route, this indicator can be a valuable tool for transportation planners to optimize the design and operation of transportation systems. Ermagun A. et al.[2] studied the fairness of traffic accessibility in Chicago and found that there was a significant inequality in the number of accessible destinations among different groups. The results highlight that the inequality of jobs, hospitals and grocery stores is the most serious among different groups. Huang B. et al.[3] studied the accessibility and spatial form fairness of urban green space in Fuzhou, including the application of GIS accessibility index to evaluate the fairness of parks, and discussed the relationship between park accessibility and street spatial form from the perspective of spatial syntax analysis.

Yan X.[4] investigated the preferences of residents in three regions of the United States (Atlanta, Puget Sound, and southeastern Michigan) for walking accessibility, public transportation accessibility, and car accessibility when choosing their place of residence. Zuo Y. et al.[5] discussed the representative indicators of walking convenience in evaluating the supply of public transportation systems. A comprehensive accessibility measurement model is proposed, which combines static and dynamic characteristics, and considers the interaction between land use, bus schedule arrangement and individual factors. Luo S. et al.[6] took the fifth ring road in Beijing as the research area, calculated the accessibility of the park based on the public perception of multi-travel mode and PM2SFCA method, and quantified the probability of residents' choice to the park by integrating the Huff model and residents' perception of the park. Cao X. et al.[7] used GIS spatial analysis technology to study the traffic accessibility of the Guangdong-Hong Kong-Macao Greater Bay Area. The results showed that the traffic accessibility in the area was ' one hour ', showing obvious ' core-periphery ' spatial characteristics. The economically developed cities on the east side have higher traffic connectivity, while most of the low accessibility areas are located in the marginal areas. Zheng Z. et al.[8] took Kaifeng City, China as an example, obtained travel time data to hospitals in different time periods through the network map API, and compared five benchmark indicators. The study found that different modes of transportation and travel time have an impact on the accessibility of medical services, providing a scientific basis for optimizing the spatial structure of hospital resources. Wang L. et al.[9] used the API real-time travel function of Baidu map, combined with spatial analysis method and scenic traffic accessibility gap index, systematically analyzed the accessibility of cars and public transport modes in 56 scenic spots in Xi 'an. Ding J. et al.[10] proposed a new gravity-based accessibility analysis method, which considers the travel characteristics of travelers and the spatial distribution of bus stops.

The accessibility is measured by service level factors and bus station accessibility, and the weight is determined by principal component analysis. A case study conducted in Beijing's actual public transport network helps to provide suggestions for improvement and shows that Beijing has a fair public transport network.

The map API has the function of providing real-time traffic data, including information such as road conditions, bus schedules, and map operating status, and the accuracy and integrity of the data are high. These data can be obtained and processed using tools such as GIS and Python, which is crucial for studying the connectivity and accessibility of large-scale transportation networks. The purpose of this study is to comprehensively evaluate the accessibility of Zhengzhou's public transport system, reveal the real situation of its service efficiency and coverage through quantitative analysis, and then provide strong data support and scientific suggestions for urban traffic planning and management. Through the accessibility analysis of the map API, we can comprehensively evaluate the service efficiency and coverage of the public transportation system, reveal potential problems and propose improvement plans. Compared with the traditional manual data collection method, the map API can realize the real-time update and accurate acquisition of data, and provide more reliable information support for urban traffic planning and management.

2 DATA SOURCES AND METHODS

This study uses the real-time traffic data provided by Baidu map API, and combines GIS technology to construct the public transport accessibility model of Zhengzhou City. By obtaining key traffic information such as bus lines, subway stations and real-time traffic conditions, the efficiency of public transport services in different regions can be quantitatively evaluated, including important indicators such as bus coverage, average waiting time, and transfer times. In addition, ArcGIS software is used for spatial visualization, and a detailed map of Zhengzhou public transport network is created. Through spatial analysis, we can intuitively understand the layout of the public transport system, identify service blind spots and hot spots, and provide a basis for future traffic optimization. At the same time, data preprocessing is performed with the Python programming environment to ensure the accuracy and reliability of the data.

Grid division is a key technology that divides the geospatial space into multiple continuous and non-overlapping small areas, which is usually applied in geographic information system (GIS) analysis to achieve fine management and efficient processing of spatial data. For the analysis of public transport accessibility, it is very important to select the appropriate meshing strategy, because it directly determines the accuracy and efficiency of the analysis. In the analysis of urban public transport, the selection of grid size needs to consider the analysis purpose, data granularity and computing resources. Smaller grids can provide more detailed analysis results, but increase the computational complexity, while larger grids simplify the calculation process but may lose local details.

In this study, the main urban area of Zhengzhou City is divided into small grids of 500m*500m, a total of 4360 small grids. The grid size is relatively reasonable, which is

very important to reveal the geographical differences of public transport services, and can provide a solid empirical basis for policy makers. Accessibility index system plays a key role in measuring the efficiency of public transport system, including bus coverage, average waiting time, transfer times, travel time and directness index. These indicators help to assess the operational status of the public transport system and provide strong support for improving services.

According to the existing literature, the evaluation methods of public transport accessibility mainly cover many types, such as distance method, cumulative opportunity method, contour method, gravity model method, probability method, frequency method, balance coefficient method, space-time method, utility method, matrix-based topology method and space syntax-based topology method. According to the time sequence, model algorithm and research accuracy of scholars ' research, these methods can be further divided into public transport site accessibility based on buffer zone, public transport area accessibility based on supply and demand model, public transport accessibility based on cost grid method, public transport accessibility based on cost grid and network analysis integration method, public transport high-precision accessibility based on high-performance graphics database and public transport high-precision accessibility based on open map API. The application of these analysis methods helps to fully understand the coverage, efficiency and accessibility of public transport networks, and provides an important reference for urban traffic planning and management. This paper uses ArcGIS and Python to obtain Baidu map API to obtain the real travel time and distance between two points, so as to achieve high-precision public transport accessibility. High-precision accessibility of public transport based on open map API Based on the accessibility of the whole process of bus travel from building to building, the whole process of traffic travel is considered, and the travel cost is obtained more accurately. The dimension of accessibility index value includes time, distance and cost, including driving and bus travel.

$$A_i = T_{walk1} + T_{wait1} + T_{run1} + \left(T_{walk2} + T_{wait2} + T_{run2} + \cdots + Tn_{transfer}\right) + T_{walk3} \quad (1)$$

High-precision accessibility analysis of public transport based on open map API, focusing on the realization of precise travel planning from building to building. This analysis method comprehensively considers various factors in the entire travel chain, covering the entire time from the starting point to the end point, including but not limited to the time to walk to the station, the time to wait for the vehicle at the station, the time to take the vehicle, and the time to transfer to other bus lines if necessary.

3 RESULTS SHOW AND ANALYSIS

3.1 Accessibility of Public Transportation in the Main Urban Area of Zhengzhou City

Based on the accessibility analysis of Zhengzhou Railway Station and Baidu map API, the accessibility of public transportation in the main urban area of Zhengzhou is stud-

ied. The analysis covers two modes of travel, driving and public transport, taking into account indicators such as distance, time and cost. The following is a visual map of the accessibility analysis of public transportation in the main urban area of Zhengzhou City. Figure 1 is the distance accessibility of the main urban area with the starting point of Zhengzhou Railway Station and the driving mode, and figure 4 is the distance accessibility of the bus mode. Figure 2 is the time accessibility of driving mode, and figure 5 is the time accessibility of bus mode. Figure 3 shows the cost accessibility of driving mode. The starting price of taxi charging standard city is 10 yuan, including 3 km mileage. After more than 3 km, 2.6 yuan per km is added. Figure 6 shows the cost accessibility of bus mode, and the charging standard is based on bus transfer.

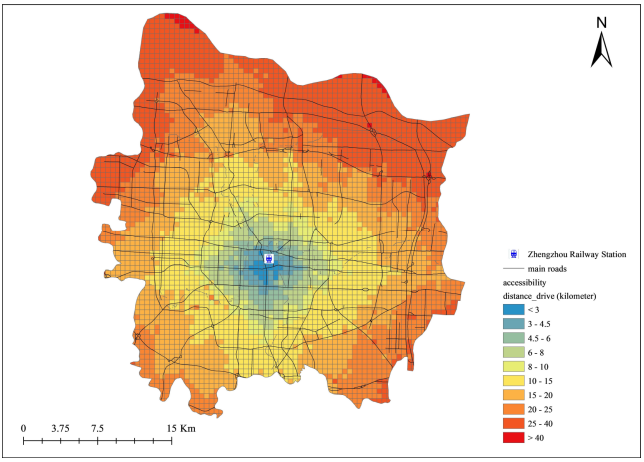

Fig. 1. Driving distance

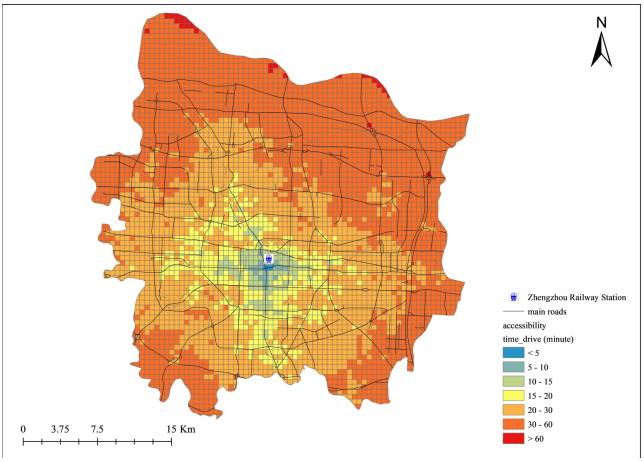

Fig. 2. Driving time

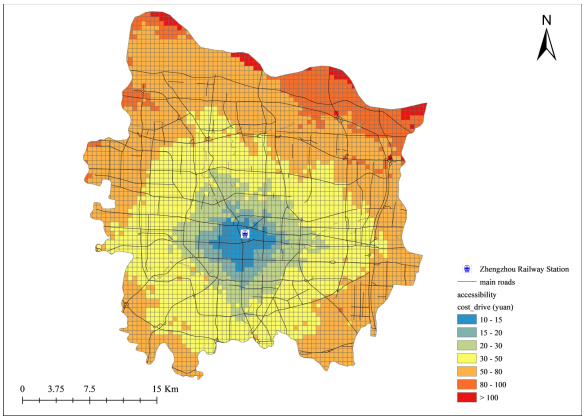

Fig. 3. Taxi cost

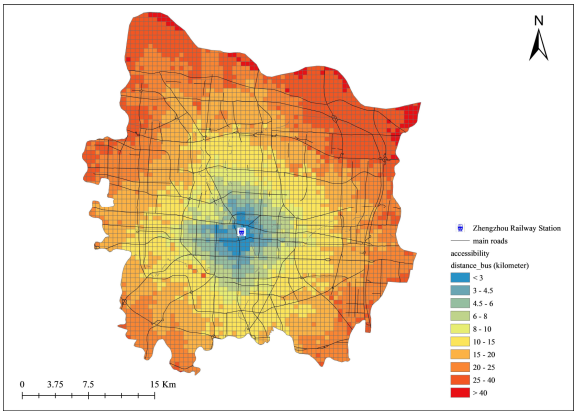

Fig. 4. Bus distance

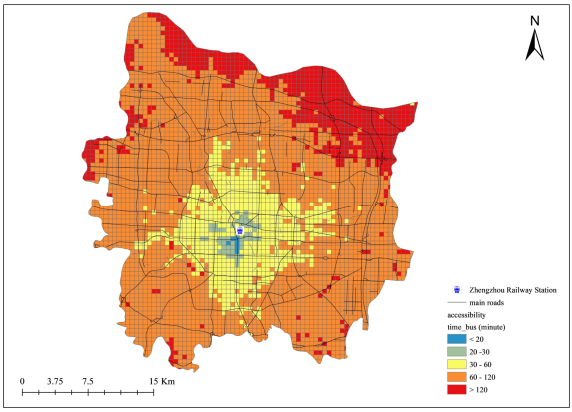

Fig. 5. Bus time

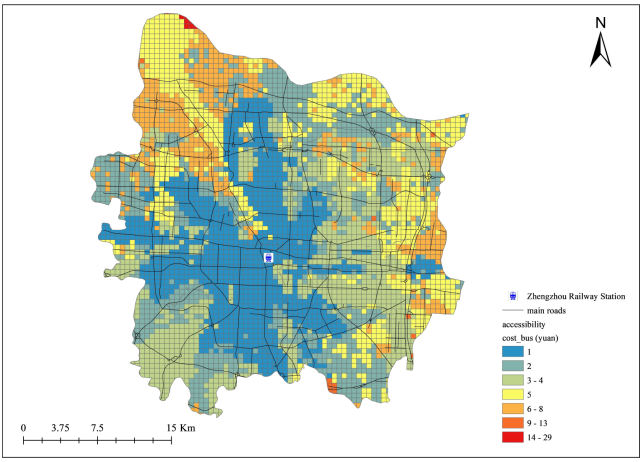

Fig. 6. Bus cost

3.2 Analysis of Influencing Factors of Public Transport Accessibility

In Zhengzhou City, the accessibility of public transport is an indispensable part of urban planning and development. First of all, site density and layout play a crucial role. As a fast-growing metropolis, Zhengzhou's high density and reasonable layout of public transport stations have greatly shortened the distance from citizens to the nearest station and improved travel efficiency. However, with the expansion of the city, the density of stations in some new districts or marginal areas is insufficient, which affects the quality of public transport services and the travel experience of citizens in these areas. Therefore, optimizing the layout of stations, especially adding stations or extending subway lines in low-accessible areas, is crucial for balancing public transport services.

Secondly, line coverage and connectivity are key indicators to measure the maturity of public transport network. The bus and subway lines in Zhengzhou have covered most of the urban areas, but the line coverage in some remote areas still needs to be strengthened. In addition, the connectivity between lines, especially the convenience of transfer, directly affects the travel efficiency of citizens. By optimizing the route design, adding transfer hubs and providing convenient transfer services, the transfer time can be effectively shortened and the connectivity and efficiency of the overall public transport system can be improved.

Furthermore, the improvement of transport infrastructure is equally important for improving public transport accessibility. Zhengzhou has made significant progress in the construction of road network, pedestrian and bicycle lanes, but there is still room for improvement. Strengthening the construction and maintenance of non-motorized lanes can not only improve the safety and convenience of non-motorized travel, but also enhance the accessibility of public transport sites, form a good interaction of multi-mode travel, and improve the traffic efficiency and public travel experience of the whole city.

Finally, understanding the population distribution pattern and travel demand is the basis for optimizing the allocation of public transport resources. The population distribution of Zhengzhou shows obvious characteristics of central agglomeration and peripheral diffusion, which means that public transport services with higher frequency and longer operation time should be provided in densely populated areas, while in marginal areas, service modes should be flexibly adjusted according to actual needs, such as introducing innovative services such as customized buses or shared buses, so as to meet diversified travel needs and enhance the overall attractiveness of public transport.

In summary, Zhengzhou City can significantly improve the accessibility and service quality of public transportation by optimizing site layout, enhancing line connectivity, improving infrastructure, intelligent dispatching and information services, and exploring diversified service models. To create a more convenient, comfortable and green travel environment for the public, help the sustainable development of urban transportation, improve the quality of life and competitiveness of the city, and lay a solid foundation for the long-term development of Zhengzhou.

4 CONCLUSION AND FORESIGHT

As a transportation hub and economic center in the Central Plains region, Zhengzhou City has shown certain advantages and challenges in the accessibility of its public transportation system in the region within the Third Ring Road. The research results show that due to the superior geographical location and the relatively perfect transportation network, the public transportation system of Zhengzhou City performs well in terms of coverage and time efficiency, which provides convenience for citizens to travel. However, the problem of accessibility in specific areas still exists. In particular, Huiji District has poor accessibility due to its remote location and unbalanced traffic layout, which needs to be further improved and optimized.

Starting from Zhengzhou Railway Station, the driving mode can cover a wide area of the main city within 1 hour, showing the high efficiency of driving. Although bus travel can reach all regions within 2 hours, it takes a long time in specific areas in the north, which highlights the urgency of bus route optimization. In addition, compared with driving, the cost of bus travel is extremely low, and most areas of the main city can be reached only by paying 5 yuan. This low-cost feature is very attractive to citizens. However, there are still some areas where bus routes need to be further optimized to achieve traffic balance and improve overall travel efficiency.

In general, Zhengzhou's public transportation has performed well in terms of coverage, efficiency and cost, but it also faces the problem of insufficient accessibility in specific areas. In order to establish a more balanced and efficient transportation network, Zhengzhou City needs to focus on improving the construction of transportation facilities, optimizing the layout of bus lines, and improving the quality of bus services to ensure that every citizen can enjoy convenient, efficient and economical travel services.

Using Baidu map API for research, starting from Zhengzhou Railway Station, the accessibility of driving and bus travel modes in the main urban area of Zhengzhou City was analyzed, taking into account three indicators: distance, time and cost. This study reveals the traffic accessibility of the main urban area. However, this study also has some limitations. First of all, the accessibility analysis based on map API is time-sensitive, which may affect the universality of the results. Secondly, although this method can support accessibility analysis of multiple travel modes, such as not taking the subway, reducing walking, short-distance travel, avoiding highways, etc., this paper does not specifically analyze these situations.

REFERENCE

1. Lucas Albuquerque-Oliveira J., Moraes Oliveira-Neto F. & Pereira R. H. M., "A novel route-based accessibility measure and its association with transit ridership," Transportation research. Part A, Policy and practice, Vol.179(2024), p.103916.
2. Ermagun A. & Tilahun N., "Equity of transit accessibility across Chicago," Transportation Research Part D: Transport and Environment, Vol.86(2020), p.102461.
3. Huang B., Chiou S. & Li W., "Accessibility and Street Network Characteristics of Urban Public Facility Spaces: Equity Research on Parks in Fuzhou City Based on GIS and Space Syntax Model," Sustainability, Vol.12, No.9(2020), p.3618.
4. Yan X., "Evaluating household residential preferences for walkability and accessibility across three U.S. regions," Transportation Research Part D: Transport and Environment, Vol.80(2020), p.102255.
5. Zuo Y., Liu Z. & Fu X., "Measuring accessibility of bus system based on multi-source traffic data," GEO-SPATIAL INFORMATION SCIENCE, Vol.23, No.3(2020), pp.248-257.
6. Luo S., Jiang H. & Yi D. et al., "PM2SFCA: Spatial Access to Urban Parks, Based on Park Perceptions and Multi-Travel Modes. A Case Study in Beijing," ISPRS international journal of geo-information, Vol.11, No.9(2022), p.488.
7. Cao X., Ouyang S. & Yang W. et al., "Transport Accessibility and Spatial Connections of Cities in the Guangdong-Hong Kong-Macao Greater Bay Area," Chinese Geographical Science, Vol.29, No.5(2019), pp.820-833.
8. Zheng Z., Xia H. & Ambinakudige S. et al., "Spatial Accessibility to Hospitals Based on Web Mapping API: An Empirical Study in Kaifeng, China," Sustainability (Basel, Switzerland), Vol.11, No.4(2019), p.1160.
9. Wang L., Cao X. & Li T. et al., "Accessibility Comparison and Spatial Differentiation of Xi'an Scenic Spots with Different Modes Based on Baidu Real-time Travel," Chinese Geographical Science, Vol.29, No.5(2019), pp.848-860.
10. Ding J., Zhang Y. & Li L., "Accessibility measure of bus transit networks," IET Intelligent Transport Systems, Vol.12, No.7(2018), pp.682-688.