Factors of Accessibility Metrics and Research Progress

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Abstract. Accessibility studies are an important concept in urban transport systems and play an important role in human geography and regional economic studies. Due to the abstract nature of the concept of accessibility, it is easy to have a one-sided understanding and ambiguous knowledge of accessibility. In order to understand accessibility accurately, this paper summarize the concept of accessibility and its influencing factors. In addition, as accessibility research deepens, accessibility measurement methods and application areas are expanding, and this paper classifies different measurement methods and discusses their advantages, disadvantages and applications. The following conclusions are drawn: firstly, according to the needs of the research object and the characteristics of the facilities, the factors influencing accessibility are divided into four types of factors: transport system factors, land resource use, time description and individual characteristics; secondly, according to the purpose and conditions of the research, the broad categories of accessibility research methods can be divided into three types: metrics based on mathematical statistics, metrics based on geometric networks and metrics based on topological networks; thirdly, different Thirdly, different accessibility research methods have different scope of application, and each has its own advantages and disadvantages. In the future, accessibility research can be improved in four directions: spatial-temporal research, adoption of appropriate accessibility methods to avoid model shortcomings, research on topological metrics and construction of a perfect accessibility metric system. In this paper, the concept of spatial accessibility and the accessibility metrics of public service facilities in existing research are reviewed, and the different methods used are compared and analyzed, in the hope of providing assistances in the knowledge and selection of relevant research methods.

Keywords: Acessibility; concepts, influencing factors, research methods, content analysis.

1. Introduction

The term accessibility was first coined in 1959 by Walter G. Hansn, who defined accessibility as the potential for interaction. However, as accessibility is a flexible concept, accessibility has been defined differently by different scholars at different times. In this paper, accessibility is divided into three categories according to the traditional interpretation of accessibility, the first being Hansen's definition of location accessibility. Accessibility is the ease of overcoming a spatial obstacle; a location with a high spatial obstacle to other locations is poorly accessible. The emphasis is on location, distance and ease of access. The second category, defined by Ben Akiva & Lerman, is effect accessibility. Effectiveness accessibility is the amount of development that can be approached per unit of time, and the more development that can be approached, the better the accessibility of the location. The third category is the Lenntorp definition of spatio-temporal accessibility. Spatio-temporal accessibility is a measure of accessibility based on theories of temporal geography and human-based research paradigms, and is also an important indicator of individual behavioral space and quality of life at a micro level. However, the implementation of this measure is limited by the high demand for micro-individual behavioral data [1]. However, the implementation of this measure is limited by the high demand for micro-individual behavioral data.

Although the concept of accessibility is perceived differently by different scholars, there are some similarities in the nature of accessibility. The magnitude of a calculated accessibility value is not explanatory itself, only when the accessibility values of individual locations in area are compared. Accessibility is not a quality of the location itself, but rather a reflection of the location's position or locality within the region as a whole. If access between two locations is not unidirectional, then

accessibility values have two-way reciprocity: the value of access from A to B is equal to the value of access from B to A. Although accessibility is an indicator of the interaction between two locations that overcomes spatial barriers, this interaction generally occurs between two active entities (e.g., residents and jobs), i.e., the calculation of accessibility between entities is mediated by space. Spatial accessibility is equivalent to the accessibility of human activities [2].

Accessibility has been expanding due to the deepening of the concept and the increasing improvement of the measurement methods, and the application areas of accessibility have been expanded. The first is the study of the impact of the spatial pattern of transport networks on regional development, which considers the evolution of regions and the development of transport networks as a spatial interaction process, and evaluates the access to development opportunities and the ability to control markets through the effective measurement of transport network structures by accessibility indicators; the second is the evaluation of the regional effects of new transport infrastructures, which considers that changes in accessibility cause changes in the value of the corresponding locations in the region, thus widening or reducing the differences in regional economic development; the third is the analysis of site selection and The third is the siting analysis and location evaluation of the proximity of social sectors or social service facilities to various impact factors such as distance, the siting analysis of various facilities, and the monumental location analysis of the layout of facilities and the human living environment; the fourth is the study of landscape and architectural design and landscape planning [3]. The fourth is the study of landscape architecture and design and landscape planning.

The main objective of this article is to provide an insight into the study of accessibility in the context of the expanding field of application of accessibility concepts in transport network construction, town development studies and site selection analysis. Firstly, the paper briefly introduces the concept of accessibility, its nature and the factors influencing it. The paper then elaborates on three types of accessibility metrics: mathematical and statistical-based metrics, geometric network-based metrics and topological network-based metrics, and classify their advantages, disadvantages and application areas in comparison. Finally, the development of accessibility research is discussed in relation to current accessibility research.

2. Factors Influencing Spatial Accessibility

Depending on the needs and characteristics of the target population, the types of factors influencing spatial accessibility and the corresponding degree of influence may vary, which determines the method of measuring accessibility. Considering only transport system factors is the basic level of application, considering both transport system factors and land resource use factors is the higher level of application, and considering a combination of transport system factors, land resource use, time description and individual characteristics is the highest level of application [4]. The highest level of application is the combination of four factors: transport system factors, land resource use, time description and individual characteristics.

2.1. Land Resource Use Factors

The geospatial carving of accessibility size is based on the spatial distance between nodes and characterizes the accessibility size by different measurements. One is the Euclidean distance, i.e., the straight-line distance, applied to accessibility studies over short distances unaffected by traffic roads; the other is the traffic distance, the size of the distance from node 1 to node 2 using traffic means.

2.2. Traffic System Factors

The transport system includes the density of road classes, the number of stations and the size of the development status of the network in the study area. The number of transport systems is used to portray accessibility, and is usually used to tailnote regions at the prefecture and county level, where accessibility is better the more developed the transport infrastructure.

2.3. Time-describing Factors

The use of time to portray accessibility size is mainly based on the time spent between two nodes and characterizes accessibility size through different measurements. The time distance is measured in two main ways, the time spent is calculated based on the distance and speed travelled all the time, and the time between two nodes is obtained directly from the train timetable and is mainly used in railway research.

2.4. Individual Characteristic Factors

Individual characteristic factors are also important aspects in the study of accessibility, including cost distance, economic affiliation, differences in the center of gravity of accessibility, and the size of supply and demand points all have an impact. Since accessibility is a relative concept and comparisons between different accessibility points are needed to obtain the magnitude of accessibility, it is necessary to standardize and sum up the facility points in the region.

3. Spatial Accessibility Metrics

Spatial accessibility measures can be applied to a wide range of spatial scales, from the fine intra-urban scale to the urban, regional and national macro scales, depending on the application requirements. The various metric methods, because of their different fields of application and research objects, are characterized by their own representative research work, such as statistical analysis, the cumulative chance method, the contour method, the two-step moving search method, the potential model, the Hoover model, etc. and improved forms of these. They can be implemented in different forms and means, and these methods can be grouped into three categories: metrics based on mathematical statistics, metrics based on geometric networks and metrics based on topological networks.

3.1. Method Based on Mathematical Statistics

Data are obtained by means of questionnaires, interviews and on-site observations, and statistical principles and regression techniques are used to analyze and sort out resistance factors and evaluation criteria for accessibility, to obtain a measure of accessibility, the underlying factor of which is distance or opportunity accumulation [5].

The method based on mathematical statistics has a wide range of applications and has the advantage of considering the factors influencing accessibility more comprehensively, including other factors of the built environment and socio-economic indicators as explanatory variables in the statistical model [6]. It has the advantage that other factors of the built environment and socio-economic indicators are also included as explanatory variables in the model. Its calibration and validation are robust and it has clear and concise results. However, the disadvantages of this method are that it lacks dimensionality, has many parameters and variables, does not easily lead to a uniform calculation method that can be replicated in planning and design, and is not ideal for measuring individual aspects of accessibility [7]. It is also not ideal for measuring individual aspects of accessibility.

3.2. Geometric Network

Geometric networks are more realistic geometric representations of the internal laws of real traffic systems, and this approach is more widely applicable and less restricted by spatial scale, and can be applied to a wide range of spatial scales, but not to microscale accessibility studies. There are three general types of approaches to understanding and measuring spatial accessibility based on geometric networks: based on spatial blocking, based on opportunity accumulation, and based on spatial interactions.

3.2.1 Based on spatial blocking

The spatial barrier-based approach analyses accessibility from a purely morphological point of view, based purely on graphical theory to study the accessibility of network nodes in a region. The degree of spatial barrier is calculated and the lower the barrier, the better the accessibility. Accessibility measures based on spatial blocking were first proposed in the 1850s, and in 1971 the scholar Ingram proposed relative accessibility and combined accessibility.

The advantages of spatial barrier-based metrics are that the results of accessibility measurements can be obtained at a macro level, they are straightforward to understand, the data can be easily obtained and collated and they are easy to calculate. The disadvantage is that it is not very adaptable and its application is limited.

The most commonly used methods for measuring accessibility based on spatial separation are the minimum proximity method and the cost-weighted distance method. The minimum proximity method measures accessibility by calculating the distance from the origin to the destination, and is one of the most widely used methods because of its low data requirements, simple calculation and intuitive results. The cost-weighted distance method uses the network distance to represent the distance between the origin and the nearest destination.

3.2.2 Based on cumulative opportunities

The cumulative opportunity-based approach emphasizes the cumulative exposure of a point to opportunities within an isochronous range and focuses on the ease with which cities can approach development opportunities. The spatial accessibility indicator based on opportunity accumulation is the opposite of that based on spatial barriers, where accessibility values increase with distance. It refers to the number of workplaces and job opportunities that residents can reach within a certain travel time from their place of residence, using a certain mode of transport. The basic idea behind the cumulative approach is that there are different opportunities for development at different times of the day, and that given enough time, residents can approach all opportunities, and the greater the number of opportunities, the higher the accessibility [8]. The higher the number of opportunities, the higher the accessibility.

Accessibility measures based on cumulative opportunities include the cumulative opportunity method and the contour method, which were developed from the distance method in the 1970s.

The advantages of a cumulative opportunity-based measure are that it is consistent with common knowledge that the greater the distance the greater the opportunities for development, and that it provides a clear representation of the distribution of the number of opportunities at spatial intervals within a given distance range, allowing comparisons of accessibility between different points. At the same time, the disadvantage of this method is that accessibility can produce different results depending on the given distance and is subject to subjective factors. The cumulative opportunity method and the contour method are often used based on the accumulation of opportunities.

The cumulative opportunity approach will first set the cost of travel and use the number of opportunities available from a point within this cost range as an indicator of accessibility. The cumulative opportunity method takes into account the size of the supply point based on the distance method, i.e., there are differences in the service radius of different types of public service facilities. The contour method, on the other hand, is based on the cumulative opportunity method, which further classifies the cost of travel and accumulates the number of opportunities according to the graded cost, the higher the number the better the accessibility. However, the grading of costs requires the selection of different contours based on experience, and it defaults to the same scale of attractiveness at each destination, ignoring diversity.

3.2.3 Based on spatial interactions

Based on spatial interactions focusing on the strength of interaction between the point of departure and the destination examines the impact of land use and development opportunities on accessibility, i.e., the ease of reaching the destination of the activity. It is the interaction or interaction potential

between the point of departure and the point of destination; the greater the interaction force between the two points, the higher the accessibility.

Spatial interaction-based measurement is the most widely used accessibility evaluation method in recent years. Its advantage is that it takes into account a wide range of factors, including traffic factors, distance, the size of the origin and destination points and the interaction forces between them. The disadvantage of this method is that it is more complicated to calculate and some of the parameters in the model are more subjective [9]. The disadvantage of this method is that it is more cumbersome to calculate and some of the parameters are more subjective.

The spatial accessibility methods based on the spatial interaction method are the gravity model, the two-step movement search method and the Hoover model. The gravity model is also known as the potential model and the potential energy model. The gravity model measures accessibility by combining the interaction forces between supply and demand points with the characteristic that spatial effects decay with distance; the greater the force between two points and the smaller the distance, the higher the accessibility. The key point of the gravity model is the determination of the distance decay function. The gravity model is more comprehensive and the model is more adaptable, but it is more cumbersome to calculate and the distance decay function varies widely in its adaptability. The two-step shift search method, also known as the Gaussian two-step shift search method, is an extension of the gravity model and was proposed by Radke in 2000. The method requires a pre-determined limit of travel cost including distance or time for the supply point at the demand point. Using the supply and demand points as the basis and the limit travel cost as the radius search, two searches are completed and the number of facilities available within the radius is calculated; the greater the number, the higher the accessibility.

The Hoover model adds spatial behavioral options to the gravity model, taking distance into account. The Hoover model assumes that "any one facility serves all spatial areas, but the probability of visiting a service facility varies in magnitude."

3.3. Topology-based Networks

Topological networks place more emphasis on the connectivity between elements and are more powerful for transport networks such as airlines, subways and bus roads. Analysis methods based on topological networks include matrix methods and spatial full stops, of which spatial full stops are more applicable to the accessibility of street network systems.

3.3.1 Matrix method

Abstract the traffic network as a topological network, construct the overall accessibility matrix through the network criticality matrix and the shortest distance matrix through the network connectivity matrix, and then calculate the accessibility level of the nodes based on these two matrices [10].

3.3.2 Spatial periods

The spatial full stop was proposed by Hillier in 1984 to analyze the accessibility between network centers and nodes in a two-dimensional street network, focusing on the graphical visualization of street connectivity, correlation and spatial topological relationships, with the main indicators being depth, average depth and integration. Depth is the shortest topological distance between spatial nodes. Average depth is the mean of the total depth from a node to any other node. Integration reflects the degree to which a node is aggregated or disconnected from other nodes in the system [11].

3.4. Spatial Accessibility Calculation Methods

This paper discusses and classifies a wide range of spatial accessibility models due to the different supply and demand requirements of the origin and destination, the different scales, the different application scenarios, and the different prerequisites and application areas for spatial accessibility calculations. The accessibility measures can be classified according to the differences in network characteristics as shown in Table 1. Accessibility can be classified according to the levels of

application and influencing factors according to Table 2. The spatial accessibility measures and models can be categorized as Table 3.

Table 1. Reachability classification based on network characteristics [3].

Network characteristics	Measurement factors	Models
Geometric networks	Spatial distance, temporal distance and economic distance	Distance method, cumulative opportunity method, contour method, gravity model, equilibrium coefficient method, space-time method and utility method
Topology Network	Overall accessibility matrix and shortest distance matrix	Matrix method with spatial full stops

Table 2. Accessibility classification based on application level [9].

Application Level	Influencing factors	Models	Advantages and disadvantages
Basic applications	Transport system	Distance method	Simple and easy to use, but too few elements to consider and a big gap to reality
Higher applications	Transportation system Land use	Gravity modelling method Accumulation of opportunities method Contour method Probabilistic approach Frequency method Balancing factor method	More realistic and more widely used
Top applications	Transport system Land use Time conditions Individual characteristics	Time and space law Effectiveness method	Thoroughly considered, but complex and difficult to achieve

Table 3. Spatial reachability measurement methods and model classification [9].

Method type	Methods	Models
Based on mathematical statistics	Statistical analysis method	
Based on geometric networks	Based on spatial separation	Minimum Proximity Method Cost-weighted distance method
	Based on cumulative opportunities	Cumulative Opportunity Method Contour method
	Based on spatial interactions	Gravity model Two-step mobile search method Hoover Model
Topology-based networks	Topology	Matrix Space Periods

The advantages of mathematical and statistical-based measures of spatial accessibility are that the factors influencing accessibility are more comprehensively considered, socio-economic indicators are incorporated and the results are simple and clear. However, the disadvantage is that there are too many variables and no unified calculation method or model has been developed. It is suitable for areas that are simple and do not require rapid results. The disadvantage is that it lacks consideration of other factors such as the scale of supply and demand points, and tends to ignore the actual road

network shape, and is suitable for individual travel, logistics and emergency services where the destination point has absolute priority. The disadvantage is that it ignores the scale and attractiveness of the demand point, as well as factors such as distance decay, and is affected by subjective factors. This method is applicable to the condition of transport facilities under different spatial and temporal conditions, land use changes and the number of opportunities that can be reached in a certain period of time at different locations to understand the configuration of public facilities; the advantage of the gravity model based on spatial interactions is The transport system is analyzed in unison with socio-economic activities; the disadvantage is that the determination of the attenuation coefficient is subjective and the size and shape of the spatial area has a greater influence on the results of the study. It is suitable for the study of land use patterns, economic development potential, transport planning and town development; the advantage of the two-step movement search method is that it takes into account the scale of the supply and demand points and the spatial forces between the two points and the characteristics of decay due to distance, but the disadvantage is that the travel limit is not set, and it is suitable for comparing the accessibility of public service facilities between a single effective service radius and a service radius graded by size. The advantage of the Hoover model is that it takes into account the scale of supply points, the choice of spatial behavior and the distance factor, but the disadvantage is that it does not take into account the scale of demand points, and it is suitable for gravitational polygon service domain algorithms, such as the study on the spatial layout of train station park-and-ride spaces. Aviation networks, public networks at the urban scale, metro lines, etc. Studies on the evolution of road networks, metro lines at the urban scale, inner city blocks or parks, etc.

4. Spatial Accessibility Research Development

The issue of accessibility is a research proposition raised in the process of transforming geography from qualitative research to quantitative analysis. As accessibility research deepens and develops in conjunction with other subject areas, accessibility research can be further improved and developed in the following directions in the future.

Firstly, spatial-temporal accessibility studies. As mentioned above, there are four factors influencing spatial accessibility, and the most widely considered element in accessibility research is the spatial element, but time and space are two elements that cannot be separated from the actual understanding of the world. Therefore, the integration of temporal and spatial elements in future research is an important aspect of improving the accessibility metric [3]. This is why it is important to integrate the spatial and temporal elements into future research.

Secondly, the accessibility method is appropriate to avoid the shortcomings of the model. As accessibility is a multi-dimensional concept, the existing methods may be limited in practice due to their different scope of application, especially when individual differences affecting accessibility are ignored. Therefore, the adoption of appropriate methods according to the research needs and the strengths and weaknesses of the metrics is one of the priorities of future accessibility research.

Thirdly, topological metrics are studied. Currently, accessibility research is dominated by geometric metrics. But topological metrics are more extensive and in-depth for practical applications, especially in garden and venue design.

Fourthly, to build a suitable model for reachability metrics. According to the many accessibility metrics currently available, a comprehensive study is conducted to establish a perfect accessibility metric system, and then a suitability model for accessibility metrics is constructed, so as to realize a unified management of accessibility metrics and facilitate the suitability testing and comparative study of accessibility metrics for different metric factors and research needs in application.

5. Conclusion

With the development of modern cities and the fact that accessibility indicators can better capture the essence of urban transport problems than mobility indicators, it is possible to further consolidate the guiding ideology of urban transport planning based on 'sources' and 'flows', and to change the traditional approach of using mobility indicators only to evaluate urban transport planning schemes. This will change the traditional approach of evaluating urban transport planning solutions by mobility indicators only. With the development of accessibility, the advantages of accessibility in the selection of transport networks, facilities and urban planning are becoming more and more prominent, and the application of accessibility is becoming more and more extensive and profound. The use of accessibility is becoming more widespread and profound. In this paper, the following conclusions can be drawn from a summary comparison:

(i) Accessibility is influenced by four factors: transport system factors, land resource use, time description and individual characteristics, according to the needs of the study population and the characteristics of the facilities.

(ii) The scope of application varies between different accessibility research methods and each has its own advantages and disadvantages

(iii) Accessibility research can be broadly classified into three categories of research methods: metrics based on mathematical statistics, metrics based on geometric networks and metrics based on topological networks, depending on the purpose and conditions of the research.

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