Review

Bibliometric Analysis of Spatial Accessibility from 1999–2022

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Abstract: Spatial accessibility is an essential manifestation of social equity and spatial planning. However, when examining spatial accessibility, systematic review studies dominate the literature, with fewer studies employing evaluative and relational bibliometric approaches. Thus, to provide a comprehensive overview of spatial accessibility research from 1999 to 2022, the works of literature referenced and analyzed by the Web of Science during 1999–2022 were analyzed: bibliometrics and scientific mapping methods using R software, the biblioshiny web program, tidyverse (ggplot2), and VOSviewer. The analysis results indicate a significant increase in the number of research papers addressing spatial accessibility throughout the research period accompanied by a continuous expansion of the research area. Collaboration and research endeavors among countries in this domain have deepened, leading to a continual improvement in the quality of papers. In addition, influential journals, authors, and articles in the field of spatial accessibility were also counted. New data, methods, and technology will become substantially more critical in accessibility research.

Keywords: bibliometrics; spatial accessibility; visualization; Web of Science

1. Introduction

Spatial accessibility refers to the ability of people to reach various destinations within a certain period of time from a geographical perspective [1,2]. High levels of spatial accessibility can promote sustainable development. For example, effective public transportation systems, cycling and walking facilities, as well as measures to reduce traffic congestion can improve people’s efficiency in reaching their destinations and reduce dependence on personal cars—therefore reducing energy consumption and environmental pollution—and thus make the world more sustainable. The concept of spatial accessibility aims to remove barriers and create inclusive environments that allow equal participation and opportunities for everyone [3,4].

The purpose of studying spatial accessibility is to understand and improve the design and implementation of various systems and environments to ensure they are accessible to all individuals regardless of their abilities [5–7] or limitations [8,9]. By examining accessibility, researchers can identify shortcomings, propose solutions, and advocate for inclusive practices in different domains [10,11].

The significance of research on spatial accessibility lies in promoting equality, diversity, and social inclusion [12,13]. When systems and environments are accessible, individuals can fully participate in society [14], access education [15], and engage in social and cultural activities [16]. Accessibility also benefits a broader range of individuals, such as older adults and those with temporary impairments [17,18]. By improving accessibility, we create more inclusive societies that value and respect all individuals’ diverse needs and abilities, fostering a sense of belonging and equal opportunities for everyone [3,19].

The current research on spatial accessibility is multidisciplinary, involving fields such as geography [20], computer science [21], engineering [22], psychology [23], education [24],
and social sciences [13]. The focus is on developing practical solutions, raising awareness, and promoting inclusive practices to ensure equal access and opportunities for individuals with disabilities in various aspects of life. Research on building environment accessibility has been conducted to improve the physical accessibility of buildings, health care [19,25,26], transportation systems [27], and infrastructure [15,28].

Bibliometrics refers to analyzing books and other propagation materials using mathematical and statistical methods [29]. In light of its ability to quantify data, which includes publication quantity, research area diversity, distribution of research institutions, bibliographic coupling, co-citation analysis, and collaboration analysis [30]. Bibliometrics can utilize a knowledge map format to showcase keywords, institutions, and national links, providing a means to quantify the current state and forecast future trends within the research subject. Additionally, it aids in the identification of noteworthy literature within the research field [31–33]. Additionally, the number of references included in bibliometric methods directly affects our ability to understand the research field [34,35].

At present, there are few bibliometric analysis applications on spatial accessibility. This article intends to use Rstudio (version: 2022.12.0-353) software to conduct bibliometric analysis on spatial accessibility. Our research efforts are concentrated on answering several critical scientific questions. First, what is the overall pattern of spatial accessibility in the scientific literature? Second, what insightful information can we learn by carefully examining this trend [36]? Third, what are the future research trends in spatial accessibility?

Our study involves particular tasks that must be completed to meet these research goals. We will analyze 7091 papers from the Web of Science (WOS) Scientific Citation Indexing (SCI) Expanded database to provide complete bibliometric insights. These selected papers will be converted and examined by employing the bibliometrics R-package and biblishiny web app. We will identify well-known authors, nations, and organizations actively involved in spatial accessibility research using total citations or the H-index. Additionally, we will use keywords to analyze prior studies and find hotspots for new research in the area.

2. Data and Method

2.1. Data

The WOS Core Collection SCI Expanded and SSCI Expanded databases were chosen as the primary data sources for this study. To conduct a comprehensive search related to spatial accessibility research, we utilized an advanced search formula with the following criteria: TS = spatial accessibility. This search yielded a total of 7400 documents on WOS, with the data being updated until 10 February 2023.

2.2. Method

The process consists of five stages: research design, data collection, data analysis, data visualization, and interpretation (Figure 1) [37,38]. In the research design stage, we selected spatial accessibility as the primary focus of our study and formulated three specific research questions: the overall patterns, status of published papers, future research trend of spatial accessibility. We selected the WOS SCI Expanded and SSCI Expanded databases as the research data resources. In total, 7400 documents were found through a literature search method, which led to the data collection stage. We used a document type filter on WOS to assure the accuracy of scientific results, promote significant research questions, and guarantee the reliability of scientific communication [38]. This filter included articles, review articles, and data papers. Furthermore, because the research unit is based on years, to maintain consistency, we employed the filter feature in biblishiny, selecting papers published between 1999 and 2022 as the study’s timeframe. As a result, our final sample comprised 7091 papers. All of the files were imported into the biblishiny web program and switched to bibliometrix RData format for further study. Moving to the data analysis stage, explanatory bibliometric analysis was conducted using R software, resulting in the creation of an extensive matrix encompassing all the documents. Subsequently, in the data
visualization stage, we employed biblioshiny, tidyverse (ggplot2), and VOSviewer to generate science maps, country collaboration networks, and charts. Furthermore, Bradford’s Law was applied to unveil the distribution of journals, aiding in identifying authoritative sources. The final stage of the study entails interpretation, wherein meaningful insights and conclusions are drawn from the accumulated results obtained throughout the research process.

**Figure 1.** Research process.

### 3. Results

#### 3.1. Overview of Bibliometric Analysis

Focusing on spatial accessibility, Figure 2 illustrates the progression of scientific production over the study period. The first paper addressing this topic was published in 1999, as documented in the WOS SCI Expanded and SSCI Expanded databases. Titled “Selection and modeling of sustainable development indicators: a case study of the Fraser River Basin, British Columbia” [39], it marked the initial contribution. The number gradually increased with a modest publication count of 20 papers in 1999. Notably, after 2014, there was a rapid surge in spatial accessibility-related papers, culminating in 1090 publications in 2022. This growth corresponds to an annual rate of 19.0%. Table 1 presents significant insights into the 7091 papers published between 1999 and 2022, sourced from the WOS SCI Expanded database and SSCI Expanded database. From 1999 to 2022, an average of 308.3 spatial accessibility-related research papers were published annually. These papers garnered an average of 23.1 citations per paper, with an average paper age of 6.1 years. Notably, 21,549 authors were involved in these publications, with 461 papers authored by only one author. An average article contains three authors (3.0). We calculated the Collaboration Index by dividing the total number of authors of multi-authored articles by the total number of multi-authored articles. And the Collaboration Index in the spatial accessibility field was calculated to be 3.2 [40]. Furthermore, these papers have a total of 17,477 author keywords, reflecting the breadth of the research undertaken in this domain.
accessibility field was calculated to be 3.2 \cite{40}. Furthermore, these papers have a total of 17,477 author keywords, reflecting the breadth of the research undertaken in this domain.

**Figure 2.** Research papers of spatial accessibility from 1999 to 2021.

**Table 1.** Main information of spatial accessibility-related literature identified by the bibliometric analysis.

<table>
<thead>
<tr>
<th>Main Information</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documents</td>
<td>7091</td>
</tr>
<tr>
<td>Sources</td>
<td>1818</td>
</tr>
<tr>
<td>Timespan</td>
<td>1999–2022</td>
</tr>
<tr>
<td>References</td>
<td>266,944</td>
</tr>
<tr>
<td>Author’s keywords (DE)</td>
<td>17,477</td>
</tr>
<tr>
<td>Authors</td>
<td>21,549</td>
</tr>
<tr>
<td>Authors Appearances</td>
<td>29,810</td>
</tr>
<tr>
<td>Authors of single-authored documents</td>
<td>461</td>
</tr>
<tr>
<td>Authors of multi-authored documents</td>
<td>39,383</td>
</tr>
<tr>
<td>Authors per document</td>
<td>2.24</td>
</tr>
<tr>
<td>Co-Authors per Documents</td>
<td>4.2</td>
</tr>
<tr>
<td>Average citations per document</td>
<td>23.1</td>
</tr>
<tr>
<td>Collaboration Index</td>
<td>2.29</td>
</tr>
</tbody>
</table>

3.2. WOS Research Areas

The papers were categorized based on the WOS research areas defined by Clarivate Analytics \cite{41}. Each paper was assigned to one or more research areas within the WOS database. Throughout the study, the spatial accessibility literature spanned increasing research areas, expanding from 27 in 1999 to 108 in 2022. The linear fitting function is shown in Figure 3, and the coefficient of determination ($R^2$) of this function is 0.97; the p-value is less than 0.001. Among the top ten most prolific research areas, the following disciplines stood out: environmental science and ecology; geography; transportation; science and technology—other topics; business and economics; engineering; public, environmental and occupational health, urban studies, public administration, and physical geography. Collectively, these areas accounted for 5343 out of the total 7091 publications, representing approximately 75.3% of the entire corpus. Figure 3b illustrates the yearly progression of the
10 most prolific research areas in the field of spatial accessibility, providing insights into the shifting focus areas within the domain. Environmental science and ecology consistently maintained its dominance in terms of literature output, surpassing other areas from 2015 onwards, thus widening the gap. Science and technology—other topics, transportation, and geography notably exhibited production levels in recent years. The introduction of the SDG (Sustainable Development Goals) in 2015 [42] appears to have spurred researchers’ growing focus toward environmental and ecological changes, which can be attributed to the significant surge in publications within this field. Furthermore, environmental sciences and ecology, geography, transportation, business and economics, and urban studies emerged as the most cited research areas based on the total number of citations [43].

Figure 3. (a) Number of research areas on spatial accessibility per year. (b) Number of articles published annually in the top ten research areas of spatial accessibility.

3.3. Countries and Institutions Engaged in the Research of Spatial Accessibility

The findings reveal that spatial accessibility research has engaged the participation of 104 countries. Among these, the top five countries contributing to scientific production in this field were the USA (1609), China (1599), the United Kingdom (364), Canada (295), and Germany (285). Notably, since 2018, the number of Chinese publications has experienced a significant increase, surpassing that of the USA (Figure 4a). China’s contribution to spatial accessibility scientific production has witnessed a steady increase over the years, reaching 42.8% in 2022 (Figure 4b). Apart from the sheer number of scientific publications, the collaborative network among countries provides insight into a nation’s research prowess [44]. Figure 5 presents the global collaborations, highlighting that the USA (85) exhibited the highest number of connections with other countries, closely followed by the United Kingdom (84), Germany (69), Netherlands (66), France (63), Australia (60), Italy (54), China (53), Spain (52) and Switzerland (50). Spatial accessibility research witnessed fewer instances of collaboration among other countries, with fewer than 50 connections each. Countries that surpassed the 50-collaboration mark were recognized as central cooperation countries [44]. The USA for instance, primarily collaborated with China, the United Kingdom, Canada, and Germany, while China predominantly worked with the USA, the United Kingdom, Australia, and the Netherlands.
Figure 4. (a) Number of articles published annually of the top five countries; (b) the yearly percentage of China’s scientific production.

Figure 5. International cooperative research network of spatial accessibility research.

We conducted calculations for the total number of citations received by papers published in each country, focusing on the top ten countries with the highest citation counts. Moreover, we determined the total number of articles published and calculated the average number of citations per paper within these selected countries (Figure 6). The United States emerged as the country with the highest total citations, significantly surpassing all other countries, with a total of 51,132 citations. China followed closely with 24,129 citations, while the United Kingdom accumulated 11,140 citations. Canada recorded 8737 citations, and the Netherlands amassed 7488 citations. Germany, Australia, Spain, France, and Italy also featured in the top ten countries, with citation counts of 7306, 6371, 5287, 5179, and 4050, respectively. The disparities between the top ten countries were relatively minor regarding average article citations. The Netherlands exhibited the highest average number of citations per article, with a value of 39.6. The United States closely followed it with 31.7 citations per article, and the United Kingdom followed with 30.6 citations per article. Canada recorded
an average of 29.62 citations per article, while Australia, Germany, France, Italy, Spain, and China had average citation counts of 25.69, 25.54, 24.66, 24.55, 22.89, and 15.09, respectively. It is worth mentioning that while China demonstrates a strong performance in terms of total citations, the average number of citations per article is notably lower compared to others. This difference can be attributed to the high volume of papers published and the relatively lower quality of a significant portion of these publications. Consequently, the United States maintains a prominent position in spatial-accessibility-related research, exhibiting a leading role in the field.

Figure 6. Total and average number of citations in the top ten countries with the highest citation counts of spatial accessibility research.

On a global scale, spatial accessibility research involves the participation of 4602 institutions. To assess the influence of each institution, we examined the number of citations garnered by papers published by these research institutions. The top ten with the highest total citation counts were recognized as the most influential research institutions among these institutions. These ten institutions accounted for 858 articles, considering the achievements of the first authors affiliated with each institution. The impact of papers originating from different institutions displayed significant variation. The University of Illinois exhibited the highest number of total citations, with a count of 2596 citations. Ghent University followed closely, with 2115 citations, while Wuhan University amassed 1991 citations. The University of Oxford accumulated 1740 citations, and Harvard University garnered 1671 citations. Other notable institutions included the University of Washington with 1648 citations, Michigan State University with 1548 citations, Tsinghua University with 1515 citations, the University of North Carolina with 1356 citations, and Arizona State University with 1269 citations (Table 2).
Table 2. Top ten institutions in the field of spatial accessibility according to the total number of citations from 1999 to 2022.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Country</th>
<th>Number of Times Cited</th>
<th>Total Amount of Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Illinois</td>
<td>USA</td>
<td>2596</td>
<td>108</td>
</tr>
<tr>
<td>Ghent University</td>
<td>USA</td>
<td>2115</td>
<td>54</td>
</tr>
<tr>
<td>Wuhan University</td>
<td>China</td>
<td>1991</td>
<td>229</td>
</tr>
<tr>
<td>University of Oxford</td>
<td>UK</td>
<td>1740</td>
<td>72</td>
</tr>
<tr>
<td>Harvard University</td>
<td>USA</td>
<td>1671</td>
<td>58</td>
</tr>
<tr>
<td>University of Washington</td>
<td>USA</td>
<td>1648</td>
<td>57</td>
</tr>
<tr>
<td>Michigan State University</td>
<td>USA</td>
<td>1548</td>
<td>63</td>
</tr>
<tr>
<td>Tsinghua University</td>
<td>China</td>
<td>1515</td>
<td>63</td>
</tr>
<tr>
<td>University of North Carolina</td>
<td>USA</td>
<td>1356</td>
<td>95</td>
</tr>
<tr>
<td>Arizona State University</td>
<td>USA</td>
<td>1269</td>
<td>59</td>
</tr>
</tbody>
</table>

3.4. Scientific Journals

Spatial accessibility studies have been published in 1818 journals, and the number of annual publications has steadily grown, increasing from 20 in 1999 to 395 in 2022. To gain insights into the distribution of spatial accessibility research papers across prominent sources, we conducted an analysis. It was found that the top five journals accounted for 1079 papers, which represents 15.2% of the total publications. Conversely, 1111 journals (61.1%) contributed only a single paper each to the field, while 1722 journals (94.7%) published up to 10 papers. Figure 7 illustrates the top five journals with the highest number of published papers in spatial accessibility research: Sustainability (339), Journal of Transport Geography (299), International Journal of Environmental Research and Public Health (156), Applied Geography (155), and ISPRS International Journal of Geo-Information (130). Notably, the journal Sustainability exhibited the most significant growth rate in terms of the annual number of published papers. According to Bradford’s Law, journals can be divided into core, related, and peripheral journals according to the number of publications in the research field. For this study, there are a total of 23 core journals, including Plos One, Cities, Transportation Research Record, Land, Transportation Research Part a-Policy and Practice, Land Use Policy, International Journal of Health Geographics, Habitat International, Transportation Research Part D-Transport and Environment, Urban Studies, Landscape and Urban Planning, Remote Sensing, Computers Environment and Urban Systems, Transport Policy, Urban Forestry & Urban Greening, Environment and Planning B-URBAN Analytics, and City Science, in addition to the five journals shown in Figure 7. Their contributions have been vital in advancing research on spatial accessibility throughout the study period.

3.5. Most Influential Authors

The H-index, a widely recognized metric for assessing scientific performance based on the number of citations received by an author’s papers, was employed in this study [45]. The top ten authors with the highest H index were Kwan M.P. (21), Neutens T. (18), Farber S. (17), Horner M.W. (17), Paez A. (17), Liu Y. (16), Wang F.H. (15), Witlox F. (14), Chaix B. (13), and Gutierrez J. (13) (Table 3). Among them, Liu Y. stood out with the highest number of publications (42) and citations, establishing them as the most influential researcher in the field. The analysis encompassed a total of 7091 papers authored by 21,549 individuals. Of these papers, 519 were single-authored, contributed by 461 independent authors. On average, each paper had 4.2 co-authors, indicating the collaborative nature of spatial accessibility research. Furthermore, authors, on average, contributed 0.329 papers, underscoring the fact that researchers in this field frequently engage in collaborative efforts.
3.5. Most Influential Authors

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Table 3. Top ten most influential authors in the field of spatial accessibility ranked by the H index from 1999 to 2022.

<table>
<thead>
<tr>
<th>Author</th>
<th>H Index</th>
<th>Number of Times Cited</th>
<th>Total Amount of Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kwan M.P.</td>
<td>21</td>
<td>1344</td>
<td>36</td>
</tr>
<tr>
<td>Neutens T.</td>
<td>18</td>
<td>1380</td>
<td>20</td>
</tr>
<tr>
<td>Farber S.</td>
<td>17</td>
<td>1069</td>
<td>26</td>
</tr>
<tr>
<td>Horner M.W.</td>
<td>17</td>
<td>852</td>
<td>26</td>
</tr>
<tr>
<td>Paez A.</td>
<td>17</td>
<td>1216</td>
<td>24</td>
</tr>
<tr>
<td>Liu Y.</td>
<td>16</td>
<td>1478</td>
<td>42</td>
</tr>
<tr>
<td>Wang F.H.</td>
<td>15</td>
<td>1156</td>
<td>22</td>
</tr>
<tr>
<td>Witlox F.</td>
<td>14</td>
<td>959</td>
<td>20</td>
</tr>
<tr>
<td>Chaix B.</td>
<td>13</td>
<td>749</td>
<td>16</td>
</tr>
<tr>
<td>Gutierrez J.</td>
<td>13</td>
<td>930</td>
<td>16</td>
</tr>
</tbody>
</table>

1 The name of authors in the table are abbreviations.

3.6. Most Influential Papers

This subsection highlights the most influential papers published between 1999 and 2022, as determined by their citation count [46]. Table 4 lists the ten papers with the highest local citation score (LCS), including their authors, source, digital object identifier (DOI) information, publication year, and LCS. Among these influential papers, the one with the highest citation count pertains to a case study on accessibility evaluation utilizing an enhanced method. This paper introduces an improved version of the two-step floating catchment area (E2SFCA) method for quantifying spatial accessibility. The E2SFCA method addresses the issue of uniform access within the catchment area by incorporating weighted travel time zones that account for distance decay. The distinct advantage of the E2SFCA method lies in its consideration of distance decay in both steps, drawing upon a solid theoretical foundation derived from the gravity model. Additionally, the E2SFCA method offers practical benefits, as it can be readily implemented in geographic information systems (GIS) and is more easily interpretable [4].
Table 4. Top ten papers in the field of spatial accessibility with the highest local citation score from 1999 to 2022.

<table>
<thead>
<tr>
<th>Author 1</th>
<th>Journal</th>
<th>DOI</th>
<th>Year</th>
<th>LCS 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUO W</td>
<td>HEALTH PLACE</td>
<td>10.1016/j.healthplace.2009.06.002</td>
<td>2009</td>
<td>400</td>
</tr>
<tr>
<td>WANG FH</td>
<td>ANN ASSOC AM GEOGR</td>
<td>10.1080/00045608.2012.657146</td>
<td>2012</td>
<td>221</td>
</tr>
<tr>
<td>PAEZ A</td>
<td>J TRANSP GEOGR</td>
<td>10.1016/j.jtrangeo.2012.03.016</td>
<td>2012</td>
<td>173</td>
</tr>
<tr>
<td>DAI D</td>
<td>LANDSCAPE URBAN PLAN</td>
<td>10.1016/j.landurbplan.2011.05.002</td>
<td>2011</td>
<td>160</td>
</tr>
<tr>
<td>MAO L</td>
<td>HEALTH PLACE</td>
<td>10.1016/j.healthplace.2013.08.008</td>
<td>2013</td>
<td>146</td>
</tr>
<tr>
<td>NEUTENS T</td>
<td>TRANSP GEOGR</td>
<td>10.1016/j.jtrangeo.2014.12.006</td>
<td>2015</td>
<td>145</td>
</tr>
</tbody>
</table>

1 The name of authors and journals in the table are abbreviations. 2 Abbreviations: DOI: digital object identifier; LCS: local cited score.

As identified according to LCS, the second-most influential paper focuses on a methodological review of the accurate measurement of health resource accessibility and the equitable allocation of resources to needy areas. This review examines advancements in three crucial areas associated with healthcare accessibility inequality, namely measurement, optimization, and impact. The paper emphasizes the importance of utilizing optimization methods to enhance healthcare providers’ distribution and availability, aiming to maximize service coverage, minimize patient travel requirements, optimize the number of facilities, and ultimately promote health equity and equal access [2]. The third-most influential paper, as determined according to LCS, critically evaluates the limitations of the two-step floating catchment area (2SFCA) method in quantifying spatial accessibility for rural health services. The study highlights two fundamental areas for improvement of the 2SFCA approach: the utilization of a single catchment size for all populations and the assumption of undifferentiated proximity within a catchment, which are particularly problematic for larger catchments. The authors emphasize that while the 2SFCA method offers advantages over simple population-to-provider ratios, it should be used cautiously [3]. According to LCS, the fourth-most influential paper, conducts a comprehensive review of commonly used measures of accessibility to clarify their normative (prescriptive) and positive (descriptive) aspects. By distinguishing between these two dimensions, policymakers can modify existing policies or develop new ones. The paper suggests that combining positive and normative perspectives on accessibility can lead to improved policy outcomes [1]. As identified according to LCS, the fifth-most influential paper introduces a geographic information system (GIS)-based approach to assess spatial accessibility to green spaces and examines racial/ethnic and socioeconomic disparities in access. The study employs the Gaussian-based two-step floating catchment area (2SFCA) method to examine pronounced variations in green space access among different racial/ethnic and socio-economic groups. The findings reveal the lack of access to green spaces for African Americans and highlight poor access in socioeconomically disadvantaged neighborhoods [47]. According to LCS, the sixth-most influential paper proposes a three-step floating catchment area (3SFCA) method to address the issue of overestimating healthcare demand in healthcare resource planning. In comparison to the enhanced two-step floating catchment area (E2SFCA), the 3SFCA method effectively reduces the overestimation of healthcare demand and provides a more balanced geographic pattern of spatial access. By employing an adjusted spatial access index, the 3SFCA method also demonstrates strong potential in identifying areas with shortages of health professionals, contributing to effective resource allocation in healthcare planning [48].

The seventh-most influential paper, as determined according to LCS, introduces a novel approach for dynamically determining physician and population catchment sizes. This method effectively identifies appropriate catchment sizes by incrementally increasing the catchment until a specified base population and physician-to-population ratio are met.
Moreover, the approach offers a more detailed understanding of spatial variation in accessibility compared to using fixed catchment sizes [49]. The eighth-most influential paper, according to LCS, presents an innovative method that incorporates multiple transportation modes into estimating healthcare accessibility. The multi-mode approach provides a more realistic estimate than the traditional single-mode two-step floating catchment area method (2SFCA). It offers valuable guidance for health policymakers in designing cost-effective intervention programs [50]. The ninth-most influential paper, as identified by LCS, highlights shortcomings in measuring accessibility and equity of healthcare services. Additionally, the paper suggests various research directions for transport geographers to advance the field. Implementing the proposed suggestions will enable progress beyond the state of the art in addressing two crucial and widely recognized research challenges in the social sciences: the modifiable areal unit problem (MAUP) and the uncertain geographic context problem (UGCoP) [51]. Finally, the tenth-most influential paper evaluates the effectiveness of different improvement approaches within two categories: incorporating distance decay within a catchment and utilizing variable catchment sizes. The evaluation focuses on the performance of these improvements across rural and metropolitan populations within large geographical regions. The findings demonstrate the necessity of combining a distance–decay function and variable catchment size function for the two-step floating catchment area method (2SFCA) to measure healthcare access across diverse geographical areas accurately [52].

The most influential papers can be categorized into three distinct groups. The first category comprises papers that propose novel methods for evaluating accessibility. These papers introduce innovative approaches to measure and assess spatial accessibility, often addressing specific limitations or shortcomings in existing methods [3,4,48–50,52]. The second category consists of papers that critically review the concept and application of spatial accessibility. These papers offer comprehensive assessments of the existing knowledge within the field, highlighting key advancements, challenges, and opportunities for future research. They provide a valuable synthesis of existing literature and contribute to the theoretical and conceptual development of spatial accessibility [1,2,51]. The third category encompasses papers that investigate the various factors influencing accessibility. These papers explore the underlying determinants and drivers of accessibility, such as transportation networks, land use patterns, socioeconomic factors, and policy interventions. They analyze the complex interactions between these factors and accessibility outcomes, shedding light on the mechanisms that shape spatial accessibility patterns [47,50].

### 3.7. Examination of Past and Present Research Hotspots

This study analyzed a comprehensive dataset of 7091 papers published on spatial accessibility research between 1999 and 2022, identifying a total of 17,477 unique author keywords. Figure 8 presents the temporal trends of these keywords, with the X-axis representing the publication year and the Y-axis displaying the keywords. The graphical representation includes three quantiles of the publication years for each keyword: the first quantile (indicated by the green dot), the third quantile (represented by the red dot), and the median (depicted by the blue dot). The size of each dot corresponds to the number of papers associated with the respective keyword. The top ten keywords according to frequency were accessibility [5,53], access [25,54], equity [55,56], impact [2,57], patterns [53,58], cities [48,59,60], services [48], impacts [2,57], dynamics [61,62], and neighborhood [6,63]. Among these keywords, “accessibility” emerged most frequently; “equity” was one of the most fundamental objectives of spatial accessibility measurement, which verifies our previous results [59,64]. In terms of study content, accessibility finds applications in the study of green space [65–68], medical institutions [5,10,69], and transportation [53,55,70–72]. The scope of the study is usually limited to “cities” and “neighborhoods.” Cities are generally used as the supply-side study area scale [15,73,74]. In contrast, neighborhoods are usually the demand-side study area scale [75–77]. “Dynamics” is the prerequisite for accessibility [61,78].
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The position of the red dot corresponds to the period of publication of the most recent paper related to the keyword, the position of the green dot corresponds to the period of publication of the earliest paper related to the keyword, and the size of the blue dot corresponds to the amount of publication (Figure 8). These visual cues collectively provide insights into the research trends pertaining to the topic “urban agglomeration” \([79–81]\) and “cities” \([59,60]\) usually are the study area of transportation. “Thermal comfort” is generally related to the spatial accessibility of green spaces and is the starting point for green space accessibility studies \([82,83]\). The common issue of “walkability” \([16,84,85]\) and “ridership” \([86–88]\) inaccessibility is that they both belong to the mode of travel, and the difference is that the method of travel is different. Similarly, the difference in accessibility is reflected in the “social inequalities” of residents \([13,14,89]\).

4. Discussion and Conclusions

In light of the global trajectory of scientific literature on spatial accessibility, there has been a remarkable surge in publications across various research domains. This review employs bibliometric analysis to offer a comprehensive overview of spatial accessibility research from 1999 to 2022. For 23 years, the field of spatial accessibility research has witnessed exponential growth in published articles, with the count escalating from 20 in 1999 to 1090 in 2022. Key research countries include the United States, China, the United Kingdom (364 articles), Canada (295 articles), and Germany. Illinois University and Ghent University emerge as prominent research institutions, while influential journals encompass
the *Journal of Transport Geography, Landscape and Urban Planning*, and *Urban Studies*. Notably, influential authors in the field include Kwan M.P., Neutens T., and Farber S. The most outstanding documents are “An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians” written by Luo as the first author, “Measurement, Optimization, and Impact of Health Care Accessibility: A Methodological Review” by Wang, and “Measuring spatial accessibility to primary care in rural areas: Improving the effectiveness of the two-step floating catchment area method” by McGrail as the first author.

Findings from this study unveil significant research trends within the domain of spatial accessibility. The availability of data sources has substantially expanded, application areas have diversified, and research methods have grown increasingly multifaceted. The range of research areas has expanded annually, from an initial focus on environmental science and ecology and engineering to encompass a broader array of fields, including geography, transportation science, public environmental and occupational health, and urban studies.

Looking ahead, spatial accessibility research is poised for further growth due to the burgeoning availability of data, novel methods and tools, and the pressing need to address spatial inequalities and promote social justice. Several critical research areas are expected to gain prominence in the future:

1. Incorporating new data sources: Traditional reliance on census data and official statistics will be supplemented by more detailed and dynamic information from GPS, social media, and crowdsourced data sources. These sources provide insights into travel behavior, preferences, and experiences.

2. Integrating new analytical methods: Advanced techniques like machine learning, deep learning, and spatial econometrics will play an increasingly pivotal role in modeling complex relationships between accessibility and variables like land use, transportation networks, and environmental factors.

3. Examining the impact of emerging technologies: The advent of emerging technologies such as autonomous vehicles, ride-sharing, and e-commerce is poised to influence spatial accessibility patterns significantly. Researchers must explore the implications of these technologies on accessibility, equity, and sustainability.

Moreover, addressing spatial inequalities and promoting social justice will remain crucial in spatial accessibility research. Researchers can utilize their findings to inform policies and interventions to enhance accessibility for marginalized communities. In essence, the future of spatial accessibility research will be shaped by new data sources, analytical methods, emerging technologies, and an unwavering commitment to social justice and equity.

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