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Research Article

Enhancing Urban Healthcare Accessibility: A Systematic Review of Methodologies and Framework Development

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ABSTRACT

This research paper presents a systematic literature review of methodologies used to assess healthcare accessibility within urban environments. The objective is to identify, analyse, and synthesise the diverse methodologies and their applications as reported in studies indexed in the Scopus and Web of Science databases, with a focus on evaluating their effectiveness in addressing urban healthcare accessibility challenges. Through a meticulous search and screening process, 593 records were initially retrieved, of which 66 met the inclusion criteria after rigorous filtering and were subjected to detailed analysis. This review highlights significant methodological diversity in the field, yet reveals crucial gaps particularly in temporal integration, demographic specificity, and dynamic modelling capabilities. By evaluating these methodologies, the study constructs a comprehensive conceptual framework that integrates spatial, temporal, and population-specific factors, aiming to enhance the understanding and improvement of healthcare accessibility in urban settings. The findings suggest that while existing research provides a strong foundation for spatial analysis, there is a pressing need for more robust models that incorporate real-time data and demographic-specific considerations. This paper underscores the importance of advancing healthcare accessibility research to include dynamic and predictive modelling, offering significant implications for policymakers and urban planners committed to reducing healthcare disparities and improving public health outcomes in cities worldwide.

Keywords: Conceptual framework, Healthcare Accessibility, Methodologies, Systematic literature review, Two-Step Floating Catchment Area (2SFCA), Urban environments.

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INTRODUCTION

Rapid urbanization has significantly transformed healthcare systems worldwide, creating both opportunities and challenges for ensuring equitable access to healthcare services. According to the World Health Organization (Disability, 2023) over half of the global population currently resides in urban areas, a proportion expected to increase substantially in the coming decades. Although cities generally offer greater concentrations of healthcare facilities than rural regions, the spatial distribution of these services often remains uneven, resulting in considerable disparities in healthcare accessibility (Disability, 2023; Riley, 2012). These disparities are further exacerbated by socioeconomic inequalities, transportation limitations, demographic changes, and differences in healthcare infrastructure, disproportionately affecting older adults, low-income households, migrants, persons with disabilities, and other vulnerable populations (de Siqueira Filha *et al.*, 2022; Weeks *et al.*, 2023).

Healthcare accessibility has evolved into a multidimensional concept that extends far beyond simple physical proximity to healthcare facilities. Contemporary studies define accessibility as the interaction between healthcare supply, population demand, transportation networks, travel behaviour, affordability, service quality, temporal availability, and individual socioeconomic characteristics (Chen & Pan, 2022; Munir *et al.*, 2020). Consequently, equitable healthcare access requires not only an adequate number of healthcare facilities but also efficient transport systems, appropriate facility distribution, and healthcare services that respond to the diverse needs of urban populations (Lardier *et al.*, 2023b; Roy & Kar, 2022). These dimensions have become increasingly important as metropolitan areas experience rapid population growth, urban sprawl, and changing patterns of healthcare utilisation.

Recent evidence indicates that inadequate healthcare accessibility contributes to delayed diagnosis, preventable hospitalisations, poorer health outcomes, and increased healthcare expenditure (Chen & Pan, 2022; Patterson-Lomba *et al.*, 2016). The COVID-19 pandemic further exposed the vulnerability of urban healthcare systems by revealing substantial inequalities in the

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spatial allocation of healthcare resources and emergency medical services (Ghorbanzadeh *et al.*, 2021; Pereira *et al.*, 2021). Similarly, studies conducted in China, Brazil, Germany, South Korea, and several other countries have demonstrated that accessibility varies considerably across neighbourhoods because of differences in transportation infrastructure, population density, socioeconomic conditions, and healthcare capacity (Baier *et al.*, 2020a; Cheng *et al.*, 2020; Kang *et al.*, 2023; Liu *et al.*, 2021). These findings emphasis that improving healthcare accessibility is not solely a public health concern but also a critical objective of sustainable urban planning and social equity.

Urban planners have increasingly recognised that transportation accessibility plays a pivotal role in determining access to healthcare services. Efficient public transport systems, multimodal connectivity, walkability, and first- and last-mile accessibility substantially influence healthcare utilisation, particularly among vulnerable groups. Research on transport accessibility has demonstrated that improvements in transit connectivity, user satisfaction, and multimodal mobility significantly enhance access to essential urban services, including healthcare (Lodhi *et al.*, 2024; Sharma & Dehalwar, 2025). Furthermore, recent advances in artificial intelligence, machine learning, and intelligent mobility modelling have introduced new opportunities for developing dynamic and data-driven healthcare accessibility assessments capable of supporting evidence-based urban planning and policy decisions (Sharma & Dehalwar, 2026; Yadav *et al.*, 2026). These developments illustrate the growing convergence of urban planning, transportation science, geospatial technologies, and public health in addressing complex accessibility challenges within rapidly urbanizing environments.

The growing complexity of urban healthcare systems has stimulated the development of increasingly sophisticated methodologies for measuring healthcare accessibility. Early accessibility studies primarily relied on distance-based and provider-to-population ratios, which offered a simplified representation of healthcare availability but failed to account for travel impedance, competition among healthcare providers, and differences in service capacity (Chandra Verma & Kamat, 2025; Wang & Tang, 2013). To overcome these limitations, Geographic Information Systems (GIS) and gravity-based accessibility models emerged as powerful tools for integrating spatial relationships between healthcare demand and service supply. Among these, the Two-Step Floating Catchment Area (2SFCA) method has become one of the most widely adopted approaches because it simultaneously considers healthcare supply, population demand, and travel catchments (Luo & Qi, 2009).

Over the past decade, numerous methodological improvements have enhanced the capability of the original 2SFCA model. The Enhanced Two-Step Floating Catchment Area (E2SFCA) method introduced distance-decay functions to better represent declining healthcare utilisation with increasing travel distance (Luo & Qi, 2009). Subsequently, the Optimized Two-Step Floating Catchment Area (O2SFCA) incorporated variable catchment sizes to reflect heterogeneous urban environments more accurately (Ngui & Apparicio, 2011). Further methodological developments include the Modified Two-Step Floating Catchment Area (M2SFCA), Balanced Floating Catchment Area (BFCA), relative spatial accessibility models, multimodal accessibility models, and telehealth accessibility frameworks, each addressing specific shortcomings related to healthcare competition, transportation diversity, service capacity, and population mobility (Delamater, 2013; Liu *et al.*, 2023; Mao & Nekorchuk, 2013; Pereira *et al.*, 2021; Wan *et al.*, 2012). More recently, GIS-based network analysis, location-allocation optimisation, Multicriteria Decision Analysis (MCDA), agent-based simulation, and flow-based statistical models have substantially improved the representation of real-world healthcare accessibility by incorporating demographic characteristics, travel behaviour, environmental conditions, and healthcare utilisation patterns (Munir *et al.*, 2020; Pan *et al.*, 2023; Roy & Kar, 2022; Tang *et al.*, 2017).

The rapid advancement of digital technologies has further transformed healthcare accessibility research. Artificial intelligence, machine learning, spatial big data, and digital mobility models have enabled dynamic prediction of healthcare demand, optimisation of healthcare facility locations, and real-time accessibility assessment using heterogeneous datasets. AI-driven transportation modelling and intelligent mobility systems have demonstrated considerable potential for supporting healthcare planning by improving multimodal accessibility estimation, travel behaviour prediction, and infrastructure optimisation (Sharma & Dehalwar, 2026). Likewise, studies investigating first- and last-mile connectivity have highlighted the importance of transportation quality, user satisfaction, and multimodal integration in improving access to essential urban services, including healthcare (Yadav *et al.*, 2026). These interdisciplinary advances illustrate that healthcare accessibility should increasingly be viewed as an integrated urban planning problem rather than solely a healthcare management issue.

Previous reviews have examined healthcare accessibility from relatively specific perspectives (de Siqueira Filha *et al.*, 2022). Focused on the economic consequences and inequities associated with healthcare access among vulnerable urban populations in low- and middle-income countries, while (Wang *et al.*, 2025a) examined healthcare accessibility primarily through the lens of telemedicine (Huisman *et al.*, 2022). Investigated accessibility in relation to digital health platforms and sustainability, whereas (Boonprong *et al.*, 2025) synthesised GIS applications for healthcare accessibility specifically within the European context. Although these reviews provide important insights into particular dimensions, technologies, populations, or geographical contexts, a comparative synthesis integrating conventional spatial accessibility models, FCA variants, GIS-network approaches,

optimisation methods, multimodal accessibility, telehealth, MCDA, and emerging AI-enabled methodologies from an urban-planning perspective remains limited.

In this review, healthcare availability refers to the presence, quantity, and capacity of healthcare resources relative to population demand (Zhou *et al.*, 2026). Healthcare accessibility refers to the opportunity or ability of individuals or populations to reach and obtain appropriate healthcare services, considering spatial, transportation, temporal, socioeconomic, and individual constraints (Liu *et al.*, 2025). Accessibility measurement refers to the analytical methods and indicators used to quantify healthcare access, including distance- or travel-time-based measures, provider-to-population ratios, GIS network analysis, gravity models, and floating catchment area methods (Roy & Kar, 2022). Healthcare utilisation, in contrast, represents the actual use of healthcare services, such as consultations, hospital visits, admissions, or treatments, and is therefore considered an outcome influenced by, but conceptually distinct from, healthcare accessibility (Shah *et al.*, 2020).

Despite substantial methodological progress, the existing review literature on healthcare accessibility remains fragmented. Previous reviews have generally focused on specific dimensions of healthcare access, particular technologies such as telemedicine, selected geographical regions, vulnerable population groups, or individual methodological approaches. Consequently, there remains limited comparative synthesis of the broader range of methodologies used to evaluate healthcare accessibility in urban environments, including conventional spatial measures, Two-Step Floating Catchment Area (2SFCA) variants, GIS-based network analysis, location-allocation models, multicriteria decision analysis, multimodal accessibility approaches, telehealth accessibility models, agent-based modelling, and emerging artificial intelligence-based techniques. In addition, previous reviews provide limited discussion of how these methodologies differ in their underlying assumptions, data requirements, ability to incorporate temporal variation, treatment of population heterogeneity, and usefulness for urban planning and healthcare resource-allocation decisions.

To address these gaps, the present study systematically reviews and critically compares the principal methodologies used to assess urban healthcare accessibility. Unlike previous reviews that are limited to particular accessibility dimensions, technologies, population groups, or geographical settings, this review integrates conventional and emerging methodological approaches within a common analytical perspective. The study evaluates their methodological characteristics, strengths, limitations, and practical applications and identifies persistent gaps related to temporal integration, population-specific factors, multimodal transportation, dynamic modelling, and empirical validation. Based on this synthesis, an integrated conceptual framework is proposed that combines spatial, temporal, demographic, transportation, and dynamic or predictive dimensions of healthcare accessibility. The framework is intended to support researchers, urban planners, healthcare administrators, and policymakers in selecting and developing accessibility assessment approaches suited to diverse urban contexts.

Although several previous reviews have examined healthcare access from specific disciplinary or geographical perspectives, a comprehensive synthesis linking methodological development with its implications for urban healthcare planning remains limited.

METHODOLOGY

Search Strategy

The systematic literature review followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines adapted for bibliometric studies. The review commenced with a comprehensive search of both the Scopus and Web of Science databases. The search strategy incorporated a combination of keywords related to healthcare accessibility, such as "healthcare accessibility," "urban healthcare," and "healthcare equity," along with advanced Boolean operators. The search captured studies from 2016 to 2026 (Figure 1).

The study-selection process was conducted in accordance with the PRISMA framework. A total of 593 records were identified through database searching, comprising 351 records from Scopus and 242 from Web of Science. After removing 217 duplicate records, 376 unique records remained for further screening. Application of the predefined publication-period criterion excluded 45 records, leaving 331 studies. A further 22 records were excluded because they were not published in English, and 175 records were excluded because they did not meet the specified document-type criterion. Consequently, 134 records were retained for title and abstract screening. Following assessment of methodological relevance and alignment with the objectives of the review, 68 records were excluded, resulting in a final sample of 66 studies included in the systematic review and subsequent analysis.

Inclusion and Exclusion Criteria

Studies were included in the review when they satisfied the following criteria: (i) the study explicitly examined healthcare accessibility, spatial accessibility, healthcare service accessibility, or related accessibility assessment methodologies; (ii) the study applied or evaluated a clearly defined analytical method, model, framework, or spatial assessment technique; (iii) the study focused on urban areas or included an urban component relevant to healthcare accessibility; (iv) the article was published in English; (v) the study was published within the predefined review period of 2016-2026; and (vi) the document was a peer-reviewed journal article indexed in Scopus.

Studies were excluded when they: (i) focused exclusively on clinical outcomes without examining healthcare accessibility; (ii) addressed healthcare availability or utilisation without an explicit accessibility assessment component; (iii) were conducted exclusively in rural settings without relevance to urban healthcare accessibility; (iv) were review articles, conference papers, book chapters, editorials, reports, theses, or other non-article publication types; (v) were published in languages other than English; or (vi) fell outside the predefined publication period.

During screening, titles and abstracts were examined to determine relevance to the review objectives. Studies meeting the eligibility criteria were retained for full-text assessment. Particular attention was given to whether the study reported a clearly identifiable accessibility methodology, defined healthcare supply and population-demand components, and provided sufficient methodological information for comparative analysis (Table 1).

Data Collection and Analysis

A structured data extraction form was used to record author names, year of publication, geographic focus, study design, population targeted, methodologies employed, and key findings from the selected studies. The extracted literature was analysed using a mixed-methods approach comprising methodological analysis, thematic synthesis, and comparative assessment across the 66 included studies. To ensure consistency in evaluating the methodological quality and relevance of the selected studies, each study was also reviewed with reference to the clarity of its research objective, adequacy of data sources, transparency of the accessibility methodology, consideration of healthcare supply and population demand, methodological robustness or validation, and relevance to urban healthcare accessibility and planning. This assessment was used to support interpretation and comparison of the reviewed studies rather than as an additional exclusion criterion.

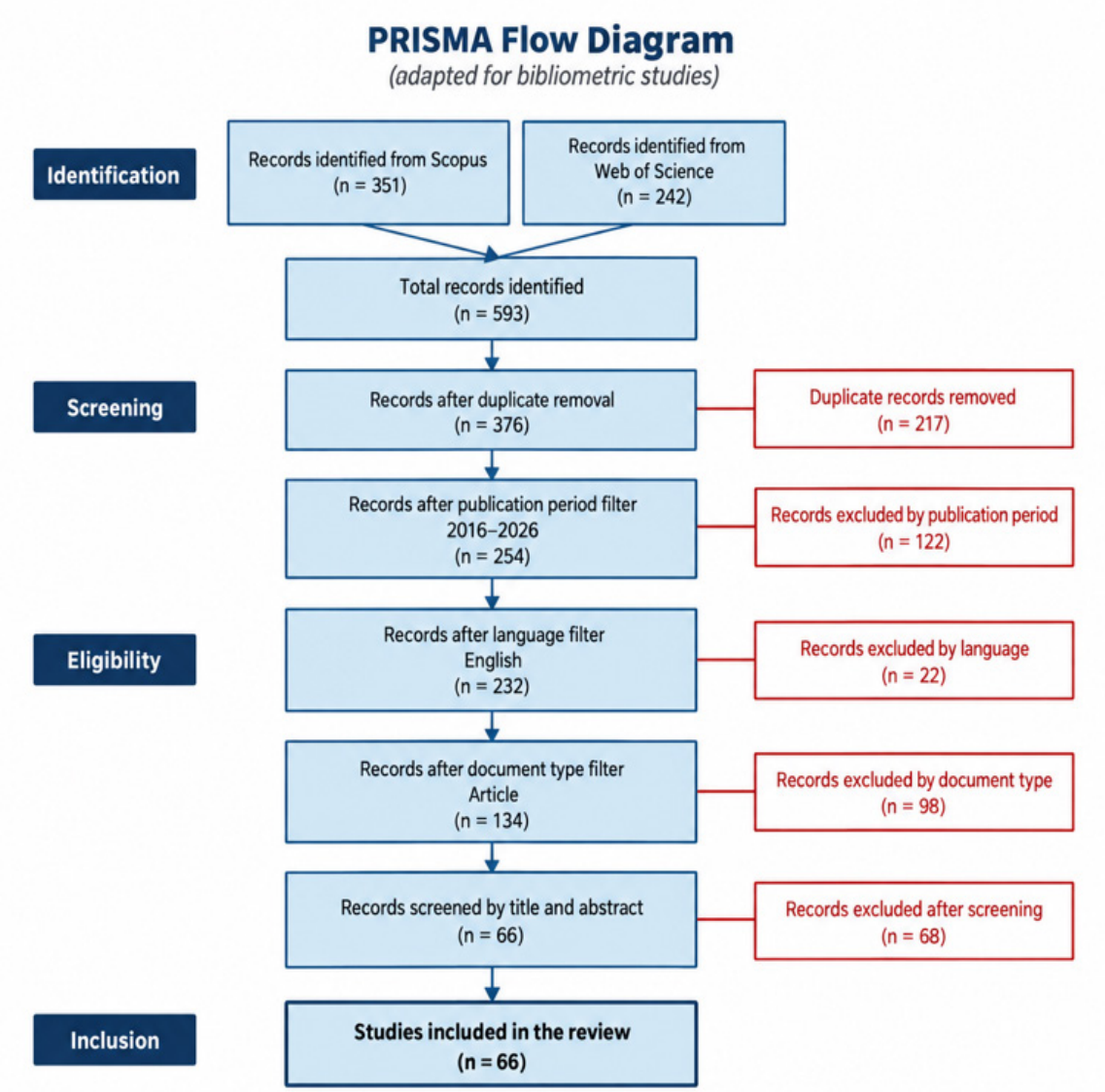


Figure 1: PRISMA Flow Diagram of the Identification, Screening, Eligibility, and Inclusion of Studies in the Systematic Review.

Table 1: Inclusion and Exclusion Criteria Applied for Study Selection.

Criterion	Inclusion	Exclusion
Topic	Healthcare accessibility or accessibility assessment	Clinical outcomes without accessibility analysis
Setting	Urban or urban-relevant context	Exclusively rural studies
Method	Clearly defined accessibility method/model/framework	No identifiable accessibility method
Publication type	Peer-reviewed journal article	Reviews, conference papers, books, reports, theses
Language	English	Non-English
Database	Scopus and Web of Science	Outside selected databases
Period	2016-2026	Outside review period

For multivariate methodological analysis, the characteristics of the 66 included studies were transformed into a binary study-by-variable matrix representing nine methodological dimensions: FCA-based methods, GIS/network/travel-time analysis, gravity/distance-decay models, location-allocation/optimisation, multimodal accessibility, spatiotemporal approaches, equity/spatial statistics, accessibility/composite indices, and MCDA/AHP. The variables were standardised prior to analysis. Principal Component Analysis (PCA) was subsequently applied to reduce dimensionality and identify dominant methodological patterns. The first two principal components were retained for two-dimensional visualisation. K-means clustering with four clusters was applied to the standardised methodological matrix, and the resulting groups were interpreted according to their dominant methodological characteristics.

RESULTS

Publication Trends

Figure 2 illustrates the temporal distribution of the 66 included studies published between 2016 and 2026. Publication activity increased substantially after 2018 and peaked in 2025 (n=14), while studies published during 2023-2025 accounted for 50% of the total sample. This pattern indicates growing scholarly interest and methodological advancement in urban healthcare accessibility research. The lower number of studies in 2026 should be interpreted cautiously because the database search was conducted before the completion of the publication year.

Geographical Distribution of Studies

Figure 3 illustrates the geographical distribution of the 66 included studies. China accounted for the largest share of studies (n=27), followed by the United States (n=11) and Canada (n=6). France, Jordan, and Iran contributed two studies each, while the remaining studies spanned European, Asian, African, Latin American, and multi-country settings. The distribution indicates a substantial geographical concentration of methodological research, particularly in China and North America, while evidence from several rapidly urbanizing low- and middle-income regions remains comparatively limited.

Methodological Diversity and Classification

The methodological coding demonstrates that FCA-based approaches remain central to urban healthcare accessibility research, appearing in 43 of the 66 studies (65.2%). GIS/network/travel-time methods were also widely applied (n=36; 54.5%), followed by equity/spatial-statistical approaches (n=16), gravity or distance-decay models (n=15), location-allocation or optimisation methods (n=10), accessibility/composite indices (n=9), multimodal accessibility (n=7), spatiotemporal approaches (n=3), and MCDA/AHP (n=1). Because several studies combined multiple methods, these categories are not mutually exclusive (Figure 4 and Table 2).

Figure 5 presents the evolution of spatial accessibility methodologies from 2003 to 2026, tracing the progressive refinement of 2SFCA variants and the emergence of novel approaches such as 2SVCA for telehealth and MCDA-based frameworks.

Methodology Usage Over Time

Figure 6 demonstrates a progressive diversification of methodological approaches across the review period. Earlier studies were dominated by conventional FCA-based methods, whereas publications after 2019 increasingly incorporated advanced FCA variants, GIS/network and travel-time modelling, multimodal accessibility, composite indices, and optimisation approaches. The strongest methodological diversification is evident during 2023-2026, indicating a shift from relatively static accessibility measurement toward more integrated, equity-sensitive, and decision-support-oriented approaches.

Keyword Co-occurrence Analysis

Figure 7 presents the keyword co-occurrence network and temporal overlay of the reviewed literature. In the visualisation, node size represents the frequency of keyword occurrence, link density indicates the strength of co-occurrence relationships, and node colour represents the average publication year of the associated research theme across the 2016-2026 review period.

The network demonstrates a highly interconnected conceptual structure centred on terms such as "health care access," "health services accessibility," "health care delivery," "accessibility," "health services," and "primary health care." Their central positions and comparatively larger node sizes indicate that these concepts form the principal intellectual core of the reviewed literature. Spatially oriented terms, including "spatial accessibility," "catchment area," and related healthcare-facility concepts, connect this central healthcare-accessibility domain with methodological approaches concerned with service distribution, travel impedance, and population-provider relationships.

The temporal overlay further indicates an evolution in research emphasis during the review period. Earlier studies are more strongly associated with broad concepts of healthcare delivery, accessibility, and healthcare disparities, whereas more recent literature increasingly incorporates themes related to spatial accessibility, vulnerable populations, equity, healthcare utilisation, and context-sensitive accessibility assessment. This transition suggests that the field has progressively moved beyond generalised measures of healthcare availability toward more differentiated analyses that account for population characteristics, spatial inequality, transportation constraints, and variations in healthcare need.

The dense interconnections among accessibility, healthcare delivery, public health, vulnerability, and spatially oriented concepts also demonstrate the increasingly interdisciplinary character of urban healthcare-accessibility research. The observed thematic evolution supports the methodological findings of this review, particularly the growing transition from conventional accessibility measurement toward equity-oriented, population-specific, multimodal, and dynamically informed approaches. Accordingly, the keyword structure provides complementary bibliometric evidence for the broader methodological shift identified across the 66 reviewed studies.

Paper Clustering by Methodological Characteristics

The K-means analysis identified four methodological groups. Cluster 1 (n=7) was characterised by multimodal FCA approaches integrating transportation-mode differences with catchment-based accessibility. Cluster 2 (n=28) was dominated by GIS, network and travel-time methods and emphasised transport impedance and spatial connectivity. Cluster 3 (n=22) represented FCA/gravity-dominant approaches centred on healthcare supply, population demand and distance-decay relationships. Cluster 4 (n=9) comprised accessibility-index and composite-enhanced FCA approaches that combined conventional accessibility measures with additional equity or composite indicators.

Figure 8 presents the PCA-based distribution of the 66 reviewed studies according to their methodological characteristics. The first Principal Component (PC1) explained 20.98% of the total variance, while the second Principal Component (PC2) explained 14.34%, resulting in a cumulative explained variance of 35.31%. PC1 was primarily characterised by positive contributions from FCA-based approaches and gravity/distance-decay models and a negative contribution from GIS/network/travel-time approaches. PC2 was most strongly associated with multimodal accessibility, while location-allocation/optimisation and spatiotemporal approaches contributed in the opposite direction. These patterns indicate that the principal methodological differentiation in the literature occurs between catchment-based supply-demand modelling, network-oriented accessibility assessment, and increasingly integrated transport and temporal approaches.

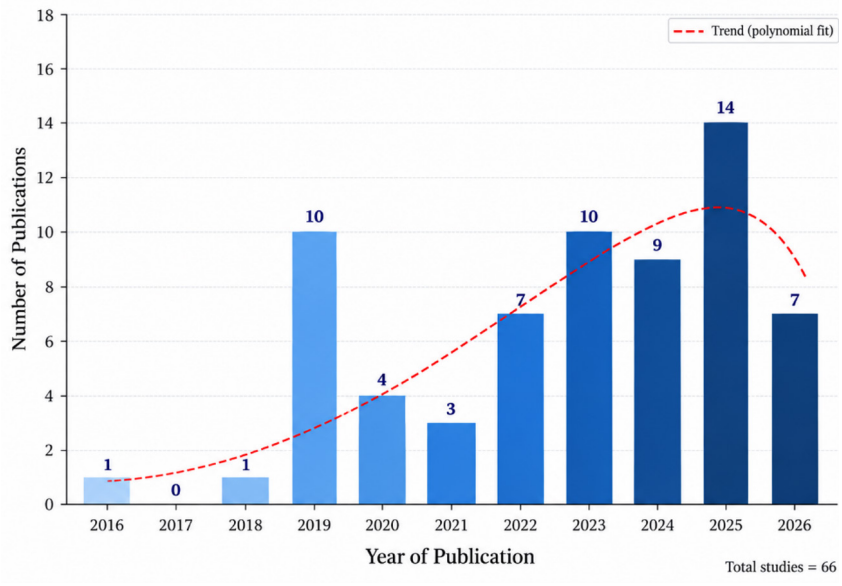


Figure 2: Publication Trends in Urban Healthcare Accessibility Research (2012-2024) with polynomial trend line.

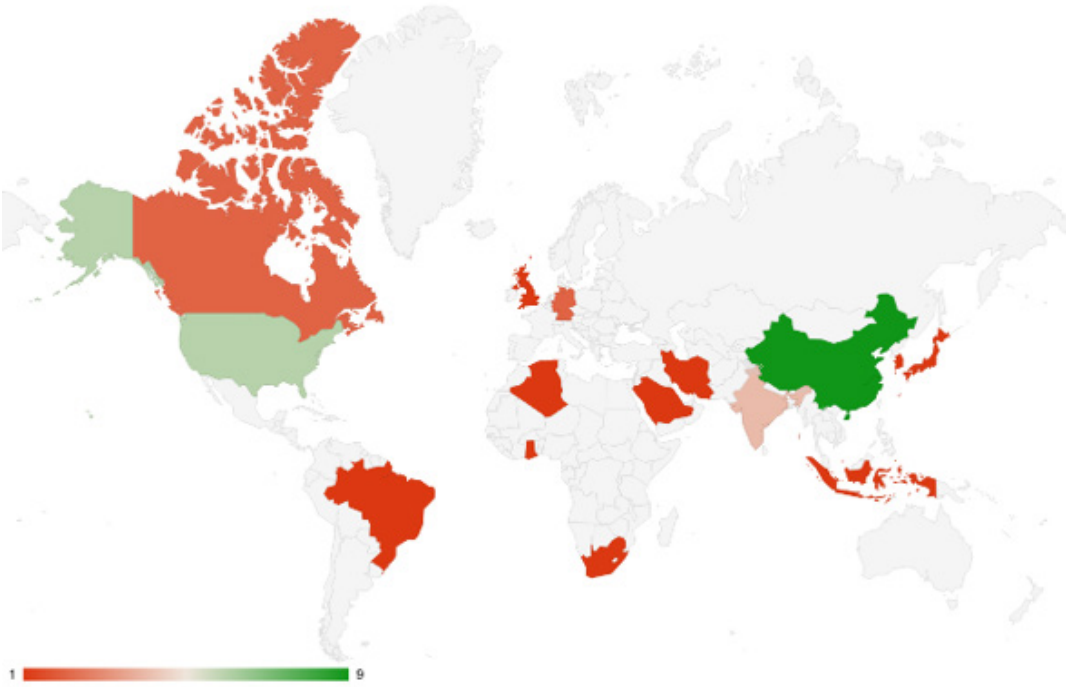


Figure 3: Choropleth Map of Publications by Country. Darker Green Indicates Higher Publication Volume.

The clustering analysis identified four methodological groups. Cluster 1 (*n*=30) was dominated by FCA and gravity/distance-decay approaches and represents the conventional supply-demand accessibility modelling tradition. Cluster 2 (*n*=26) consisted predominantly of GIS, network and travel-time approaches, emphasising transport impedance and spatial connectivity. Cluster 3 (*n*=7) comprised multimodal FCA studies integrating different transportation modes into healthcare accessibility measurement. Cluster 4 (*n*=3) contained spatiotemporal and hybrid approaches that incorporate temporal variation alongside conventional spatial accessibility dimensions.

Identification of Research Gaps

Figure 9 presents a radar chart quantifying the frequency of research gaps identified across the 66 reviewed studies. Temporal integration (*n*=29) and population-specific factors (*n*=23) emerge as the most critical and pervasive gaps, followed by dynamic modelling (*n*=5) and empirical validation (*n*=3).

The frequent identification of temporal integration as a research gap indicates that many existing spatial accessibility models treat healthcare access as a relatively static phenomenon, often overlooking clinic operating hours, seasonal demand fluctuations, and peak traffic conditions. Similarly, the prevalent gap in population-specific factors (72%) reflects insufficient consideration of demographic vulnerabilities such as age, mobility limitations, and socioeconomic status.

DISCUSSION

Relevance of Methodological Diversity

The findings of this systematic review demonstrate that healthcare accessibility research has evolved considerably over the past two decades, with an increasing diversity of methodological approaches designed to capture the complex interactions between healthcare supply, population demand, transportation systems, and urban spatial structure. Among these approaches, the Two-Step Floating Catchment Area (2SFCA) method and its subsequent variants including the Enhanced Two-Step Floating Catchment Area (E2SFCA), Optimized Two-Step Floating Catchment Area (O2SFCA), Modified Two-Step Floating Catchment Area (M2SFCA), and Balanced Floating Catchment Area (BFCA) remain the most frequently adopted techniques because of their ability to simultaneously account for healthcare supply, population demand, and travel impedance (Luo & Qi, 2009; Ngui & Apparicio, 2011; Delamater, 2013; Pereira *et al.*, 2021; Delamater, 2013; Luo & Qi, 2009; Ngui & Apparicio, 2011; Park *et al.*, 2026; Pereira *et al.*, 2021). These methodologies have substantially advanced spatial accessibility assessment by moving beyond simple provider-to-population ratios and Euclidean distance measures, enabling more realistic evaluations of healthcare service availability across heterogeneous urban environments (Lawrence *et al.*, 2026; Song *et al.*, 2018; Wang & Tang, 2013).

Despite these methodological advances, the review identifies several persistent limitations. Most existing accessibility models continue to rely on static assumptions regarding travel behaviour, healthcare demand, and service availability, thereby

overlooking temporal variations associated with clinic operating hours, congestion patterns, seasonal demand fluctuations, and emergency healthcare requirements (Pan *et al.*, 2023; Roubin *et al.*, 2025; Song *et al.*, 2018). Furthermore, conventional spatial models rarely integrate behavioural responses, multimodal transportation options, or emerging digital healthcare services such as telemedicine, limiting their applicability in rapidly evolving urban environments (Huisman *et al.*, 2022; Tang *et al.*, 2017; Wang *et al.*, 2025b).

The integrated framework proposed in this review addresses these shortcomings by combining spatial, temporal, demographic, and technological dimensions within a unified analytical structure. By incorporating GIS-based network analysis, multicriteria decision analysis, artificial intelligence, predictive mobility modelling, and real-time transportation information, the framework provides a more dynamic representation of healthcare accessibility. Recent studies on multimodal accessibility, travel behaviour, and AI-enabled mobility modelling further support the integration of transportation characteristics into healthcare accessibility assessments, demonstrating that first- and last-mile connectivity, user satisfaction, and intelligent transport systems significantly influence equitable access to essential services (Chen *et al.*, 2024b; Wang *et al.*, 2025a; Weeks *et al.*, 2023; Yadav *et al.*, 2025). Consequently, the proposed framework offers a comprehensive decision-support tool for urban planners and policymakers seeking to develop resilient, equitable, and data-driven healthcare systems capable of responding to both present and future urban challenges.

Addressing Identified Gaps

This systematic review identifies several persistent methodological gaps that continue to limit the effectiveness of healthcare accessibility assessment in rapidly urbanizing environments. Although considerable progress has been achieved through GIS-based accessibility models and the evolution of the Two-Step Floating Catchment Area (2SFCA) family, most existing studies remain predominantly spatial in nature, with limited consideration of temporal dynamics, behavioural responses, multimodal transportation systems, and emerging digital healthcare services (Huisman *et al.*, 2022; Wang & Tang, 2013; Wang *et al.*, 2022). Furthermore, many accessibility assessments rely on static datasets that inadequately represent real-world variations in healthcare demand, traffic congestion, clinic operating hours, seasonal fluctuations, and emergency situations, thereby reducing their practical value for dynamic urban planning (Pan *et al.*, 2023; Weeks *et al.*, 2023; Zhang *et al.*, 2021).

Another significant gap concerns the limited integration of population-specific characteristics within accessibility models. Existing research has increasingly recognised that vulnerable populations including older adults, persons with disabilities, low-income households, and residents dependent on public transportation experience distinct accessibility barriers that cannot be captured solely through distance-based measures

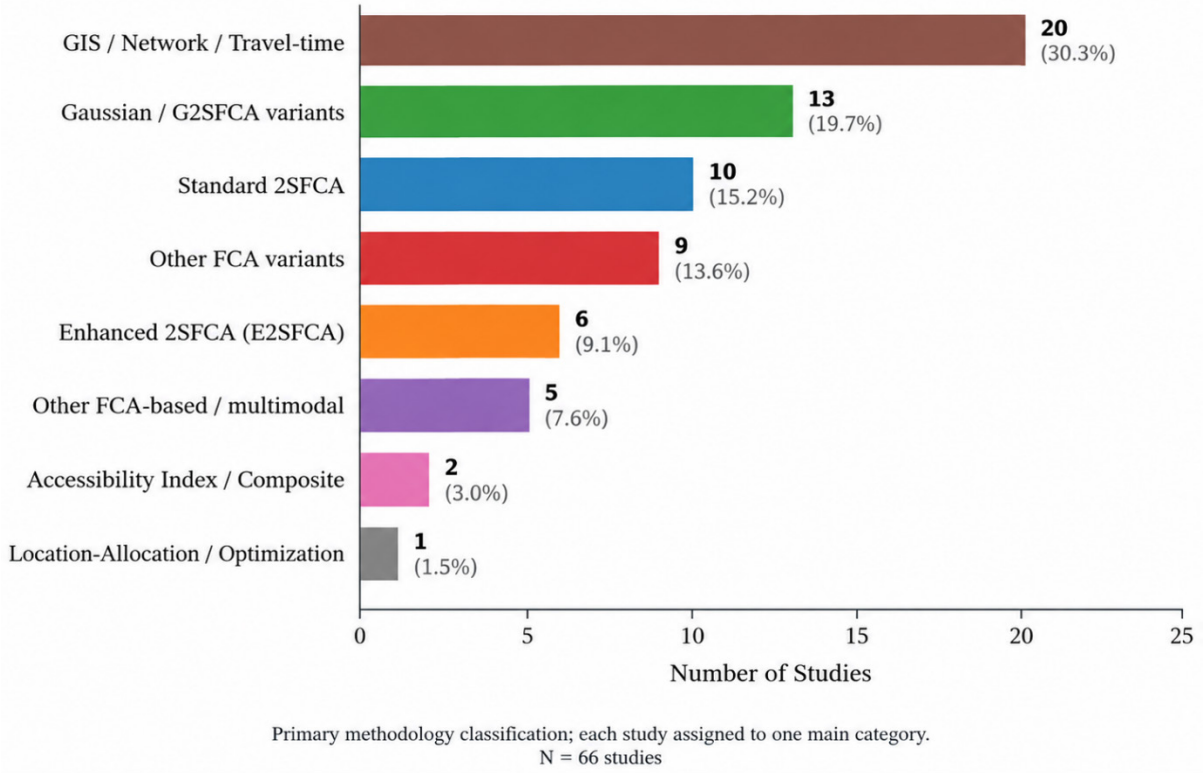


Figure 4: Distribution of Spatial Accessibility Methodologies Across Reviewed Studies (*n*=66).

Table 2: Classification and Representative Applications of Spatial Accessibility Methods Across the 66 Reviewed Studies.

Sl. No.	Spatial Accessibility Method (SAM)	Representative References from the 66 Studies (APA 7)
1.	Standard Two-Step Floating Catchment Area (2SFCA)	(Akakba & Lahmar, 2023; Alam *et al.*, 2023; Boisjoly *et al.*, 2020; Gu *et al.*, 2019; Hashtarkhani *et al.*, 2020; Hu *et al.*, 2019; Sui *et al.*, 2023; Sullivan *et al.*, 2022; Xu *et al.*, 2019)
2.	Enhanced Two-Step Floating Catchment Area (E2SFCA)	(Edmonds & Delamater, 2025; Hashtarkhani *et al.*, 2020; Lardier *et al.*, 2023a; Li & Wang, 2022; Maslamani *et al.*, 2021; Roubin *et al.*, 2025; Shah *et al.*, 2020)
3.	Gaussian Two-Step Floating Catchment Area (G2SFCA)	(Du *et al.*, 2024; Gou *et al.*, 2026; Han *et al.*, 2025a; Han *et al.*, 2025b; Li *et al.*, 2024; Meng *et al.*, 2019; Park *et al.*, 2026; Wei *et al.*, 2024; Xia *et al.*, 2022; Yang *et al.*, 2025; Zhao *et al.*, 2024)
4.	GAUSS-Probability Two-Step Floating Catchment Area (GP2SFCA)	(Tian *et al.*, 2025)
5.	Modified Kernel-Density Two-Step Floating Catchment Area (MKD2SFCA)	(Song *et al.*, 2018)
6.	Generalised Flow-Based Two-Step Floating Catchment Area (GF2SFCA)	(Chen *et al.*, 2024a)
7.	Directional Two-Step Floating Catchment Area	(Wang *et al.*, 2025b)
8.	Hierarchical Two-Step Floating Catchment Area (H2SFCA)	(Li & Wang, 2022)
9.	Telehealth-Integrated / Improved 2SFCA (i2SFCA-TH)	(Wang *et al.*, 2025a)
10.	Three-Step Floating Catchment Area (3SFCA) and Improved 3SFCA	(Li *et al.*, 2026; Shah *et al.*, 2016)
11.	Gaussian Three-Step Floating Catchment Area	(Zhou *et al.*, 2026)
12.	Integrated Floating Catchment Area (iFCA)	(Assis *et al.*, 2026)
13.	Spatial Access Ratio / Multimodal FCA-Based Accessibility	(Alam *et al.*, 2023; Boisjoly *et al.*, 2020; Guida *et al.*, 2022; Khakh *et al.*, 2019; Lardier *et al.*, 2023b)
14.	Potential and Gravity-Based Accessibility Models	(Du *et al.*, 2024; Hu *et al.*, 2019; Wang *et al.*, 2022; Zhang *et al.*, 2021)
15.	GIS Network Analysis, Travel-Time and Service-Area Models	(Ahmed *et al.*, 2019; Banke-Thomas *et al.*, 2021; Boonprong *et al.*, 2025; Cazacu *et al.*, 2025; Das *et al.*, 2023; Reshadat *et al.*, 2019)
16.	Location-Allocation and Spatial Optimization Models	(Han *et al.*, 2025a; Maslamani A. *et al.*, 2021; Pan *et al.*, 2023; Song *et al.*, 2022; Taran, 2023; Wang *et al.*, 2025a)
17.	Spatiotemporal / Space-Time Accessibility Models	(Hernández & Rossel, 2024; Park *et al.*, 2026; Roubin *et al.*, 2025; Song *et al.*, 2018)
18.	Accessibility Index and Composite Spatial-Equity Approaches	(Gou *et al.*, 2026; Launay *et al.*, 2019, 2024)
19.	Voronoi-Based Accessibility and Network Isochrone Analysis	(Boonprong *et al.*, 2025)
20.	Least-Cost Path / Network-Based Geographic Accessibility	(Bono *et al.*, 2023; Dumedah *et al.*, 2023; Friesen *et al.*, 2025; Hounménou *et al.*, 2025)

Note: Several reviewed studies employed more than one accessibility methodology or combined spatial-accessibility models with GIS network analysis, equity measures, optimisation, multimodal transport analysis, or temporal modelling. Therefore, individual studies may appear in more than one methodological category. The table presents representative methodological applications identified across the 66 included studies and should not be interpreted as mutually exclusive classifications.

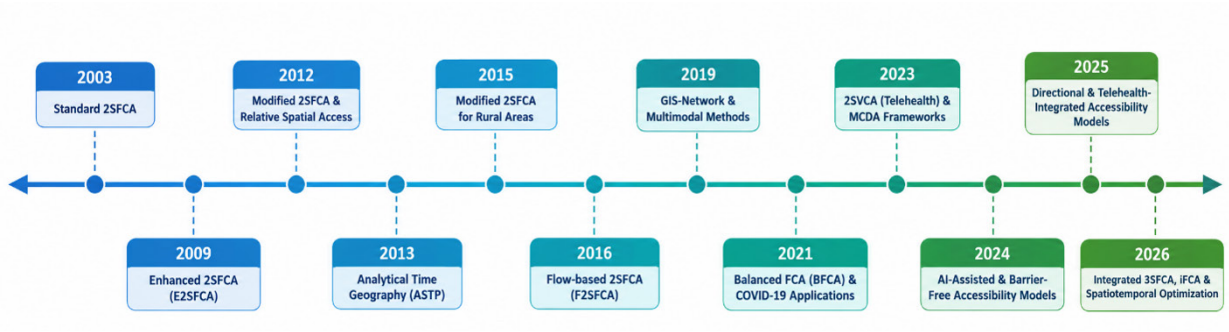


Figure 5: Evolution of Spatial Accessibility Methodologies in Urban Healthcare Research (2003-2026).

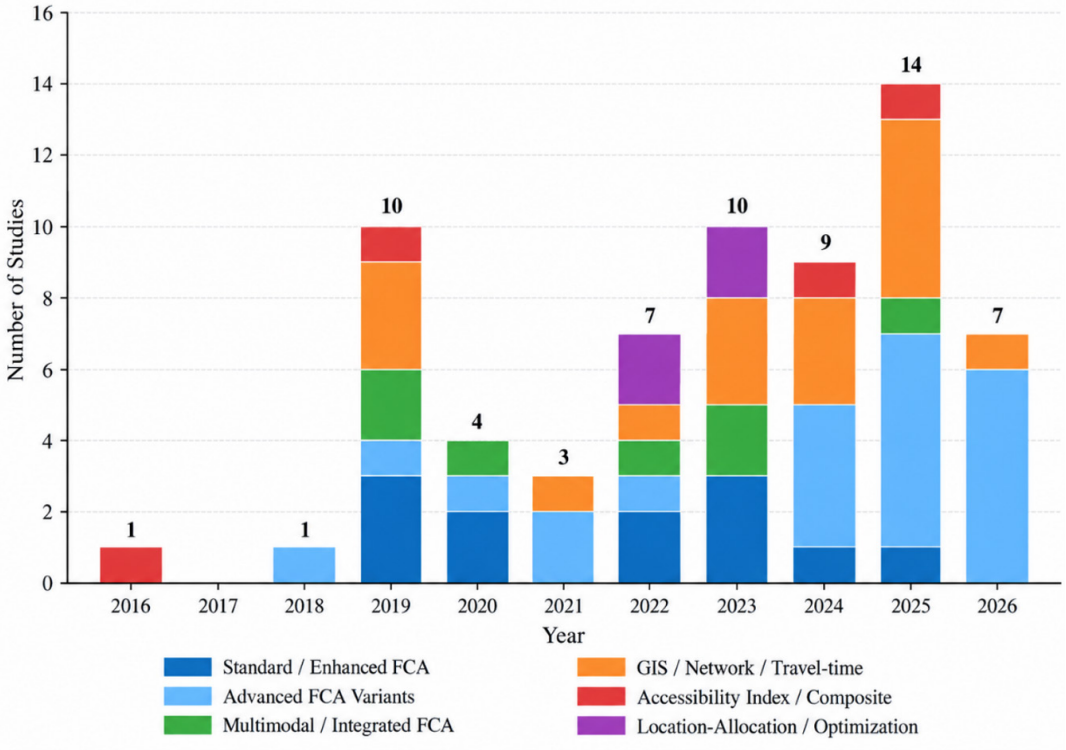


Figure 6: Distribution of Methodology Types by Year of Publication.

(Edmonds & Delamater, 2025). Similarly, relatively few studies explicitly incorporate multimodal mobility patterns, first- and last-mile connectivity, or user perceptions despite their demonstrated influence on healthcare utilisation and accessibility outcomes (Shah *et al.*, 2020; Zhou *et al.*, 2026).

The integrated conceptual framework proposed in this review addresses these shortcomings by combining spatial, temporal, demographic, transportation, and technological dimensions into a unified analytical framework. By integrating real-time GIS data, network analysis, multicriteria decision analysis, artificial intelligence, predictive analytics, and dynamic transportation modelling, the framework enables continuous assessment of healthcare accessibility under changing urban conditions. The inclusion of AI-enabled mobility modelling and intelligent transport systems further enhances the framework's ability to predict accessibility patterns, optimism healthcare resource allocation, and support evidence-based planning decisions (Han *et al.*, 2025a; Masiano *et al.*, 2019). Moreover, the framework provides a scalable and adaptable decision-support tool that can be applied across diverse urban contexts, thereby improving the responsiveness, equity, and resilience of healthcare systems while facilitating more efficient long-term urban health planning.

Enhancing Equity in Healthcare Access

Promoting equitable healthcare accessibility has become a central objective of contemporary urban planning and public health policy. The findings of this review indicate that although numerous accessibility models effectively quantify the spatial relationship between healthcare supply and population demand, relatively few explicitly account for the heterogeneous needs of different population groups. Most conventional approaches prioritise geographic proximity and service availability while overlooking socioeconomic disparities, demographic characteristics, mobility

constraints, and health-related vulnerabilities that substantially influence healthcare utilisation (Akakba & Lahmar, 2023; Baier *et al.*, 2020b). Consequently, accessibility estimates may overstate healthcare availability for vulnerable populations, including older adults, persons with disabilities, low-income households, migrants, and individuals dependent on public transportation.

Recent studies have increasingly demonstrated that equitable healthcare planning requires the incorporation of population-specific characteristics into accessibility assessment. Factors such as age, income, disability status, chronic health conditions, vehicle ownership, and transportation dependency significantly affect an individual's ability to reach healthcare facilities, even when services are geographically close (Chen *et al.*, 2024b; Cheng *et al.*, 2020). Likewise, disparities in multimodal transport availability and first- and last-mile connectivity further influence healthcare accessibility across different socioeconomic groups, particularly within densely populated metropolitan areas (Khakh *et al.*, 2019; Roy & Kar, 2022). These findings suggest that accessibility should be evaluated as a multidimensional measure of opportunity rather than merely a function of travel distance.

The integrated framework proposed in this review addresses these limitations by explicitly incorporating demographic, socioeconomic, transportation, and health-related indicators into healthcare accessibility modelling. Rather than adopting a uniform accessibility threshold, the framework enables differentiated accessibility assessments for population groups with distinct mobility needs and healthcare requirements. Furthermore, the integration of GIS-based spatial analysis, multicriteria decision analysis, artificial intelligence, and predictive mobility modelling allows planners to identify underserved communities, prioritise infrastructure investments, and optimism healthcare resource allocation under changing urban conditions (K. Chen *et al.*, 2024a; Han *et al.*, 2025b; Roy & Kar, 2022). By embedding equity considerations throughout the analytical process, the proposed framework provides a more inclusive decision-support tool that can assist governments and urban planners in reducing spatial inequalities, improving healthcare access for disadvantaged populations, and advancing the broader goals of sustainable, resilient, and people-centred urban development.

Practical Implications and Policy Recommendations

The findings of this review have important implications for urban planning, public health policy, and healthcare infrastructure development. As cities continue to expand and demographic characteristics become increasingly heterogeneous, healthcare accessibility assessment must evolve from static spatial evaluations toward dynamic, evidence-based decision-support systems. The integrated conceptual framework proposed in this study provides policymakers and urban planners with a

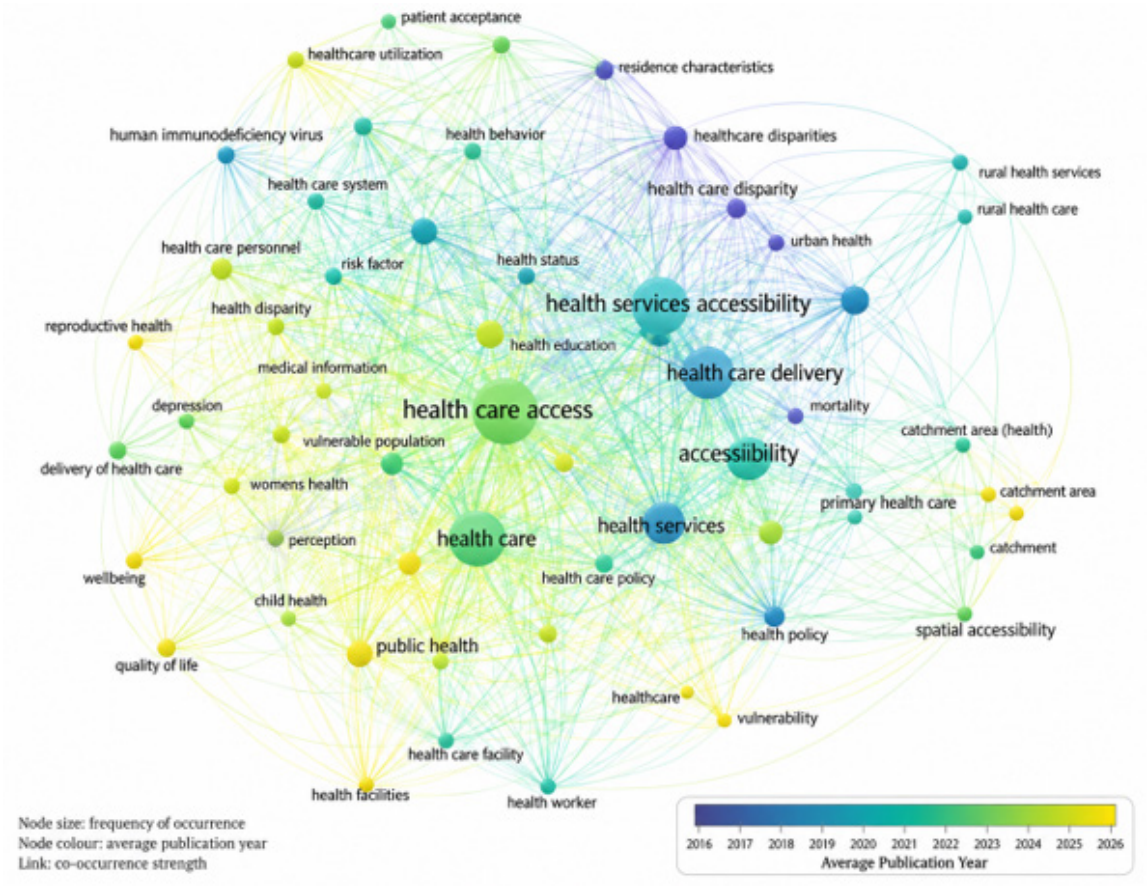


Figure 7: Keyword Co-occurrence Network Overlay Visualization (VOSviewer) Showing Temporal Shifts in Research Themes.

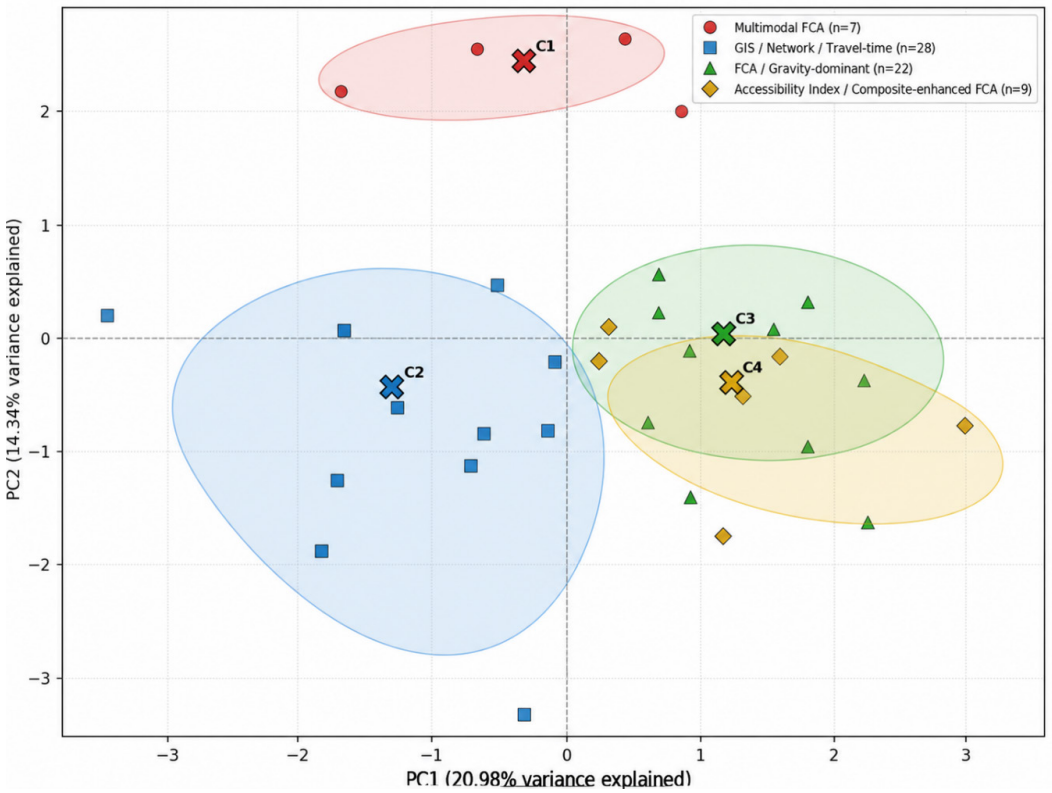


Figure 8: PCA-Based Paper Clustering Visualization Across Four Methodological Clusters.

comprehensive tool for identifying underserved areas, prioritising healthcare investments, and optimising the spatial distribution of healthcare facilities. By combining spatial accessibility measures with demographic characteristics, transportation networks, and emerging digital technologies, the framework enables more informed planning decisions that promote equitable and resilient healthcare systems (Gou *et al.*, 2026; Pan *et al.*, 2023; Yang *et al.*, 2025).

From a planning perspective, integrating real-time information into healthcare accessibility models can substantially improve resource allocation and service delivery. Dynamic variables such as clinic operating hours, physician availability, patient waiting times, public transport schedules, road congestion, and seasonal travel patterns provide a more realistic representation of healthcare accessibility than conventional static models (Boonprong *et al.*, 2025; Ghorbanzadeh *et al.*, 2021; Liu *et al.*, 2022). The incorporation of these datasets would enable healthcare authorities to respond more effectively to fluctuations in demand, emergency situations, and rapidly changing urban conditions.

The review also demonstrates the value of adopting hybrid analytical approaches that integrate GIS-based network analysis with advanced accessibility models, multicriteria decision analysis, and artificial intelligence. Such interdisciplinary methodologies can improve the identification of healthcare service gaps while supporting predictive analyses of future healthcare demand under different urban growth scenarios (Dumedah *et al.*, 2023; Roubin *et al.*, 2025; Zhou *et al.*, 2026). Furthermore, integrating first- and last-mile connectivity, multimodal transportation systems, and user-centred mobility indicators into accessibility assessments can improve healthcare access for populations dependent on public transport and active mobility (Banke-Thomas *et al.*, 2021; Boisjoly *et al.*, 2020; Lardier *et al.*, 2023b).

Future research should prioritise four key directions. First, accessibility models should integrate temporal datasets, including clinic operating hours, healthcare workforce availability, patient waiting times, traffic congestion, and real-time mobility information. Second, hybrid modelling frameworks that combine 2SFCA variants with GIS, multicriteria decision analysis, machine learning, and artificial intelligence should be further developed and empirically validated across diverse urban contexts. Third, equity-oriented accessibility metrics should explicitly account for demographic and socioeconomic characteristics such as age, disability, income, gender, and transport dependency to better represent the needs of vulnerable populations (de Siqueira *et al.*, 2022; Lardier *et al.*, 2023b; Roubin *et al.*, 2025). Finally, future studies should evaluate the applicability of dynamic accessibility frameworks in rapidly urbanizing cities of low- and middle-income countries, where infrastructure limitations, population growth, and socioeconomic inequalities present unique planning challenges. Collectively, these directions will support the development of more adaptive, equitable, and sustainable healthcare systems capable of responding to evolving urban healthcare needs.

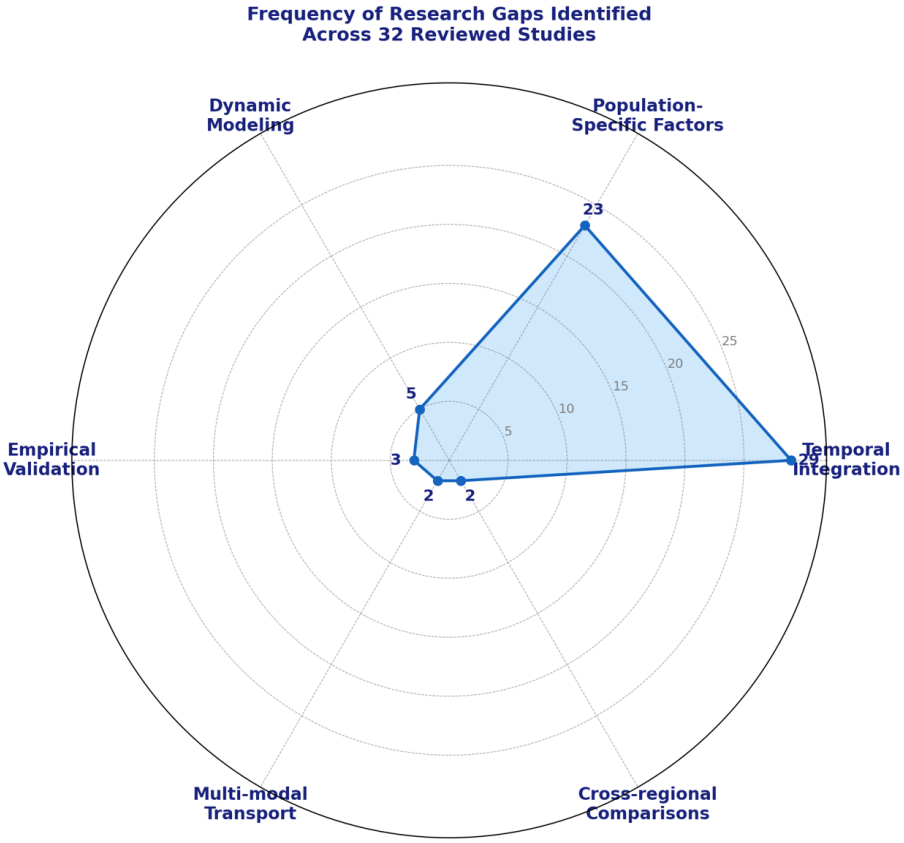


Figure 9: Radar Chart of Research Gaps Identified Across 66 Reviewed Studies.

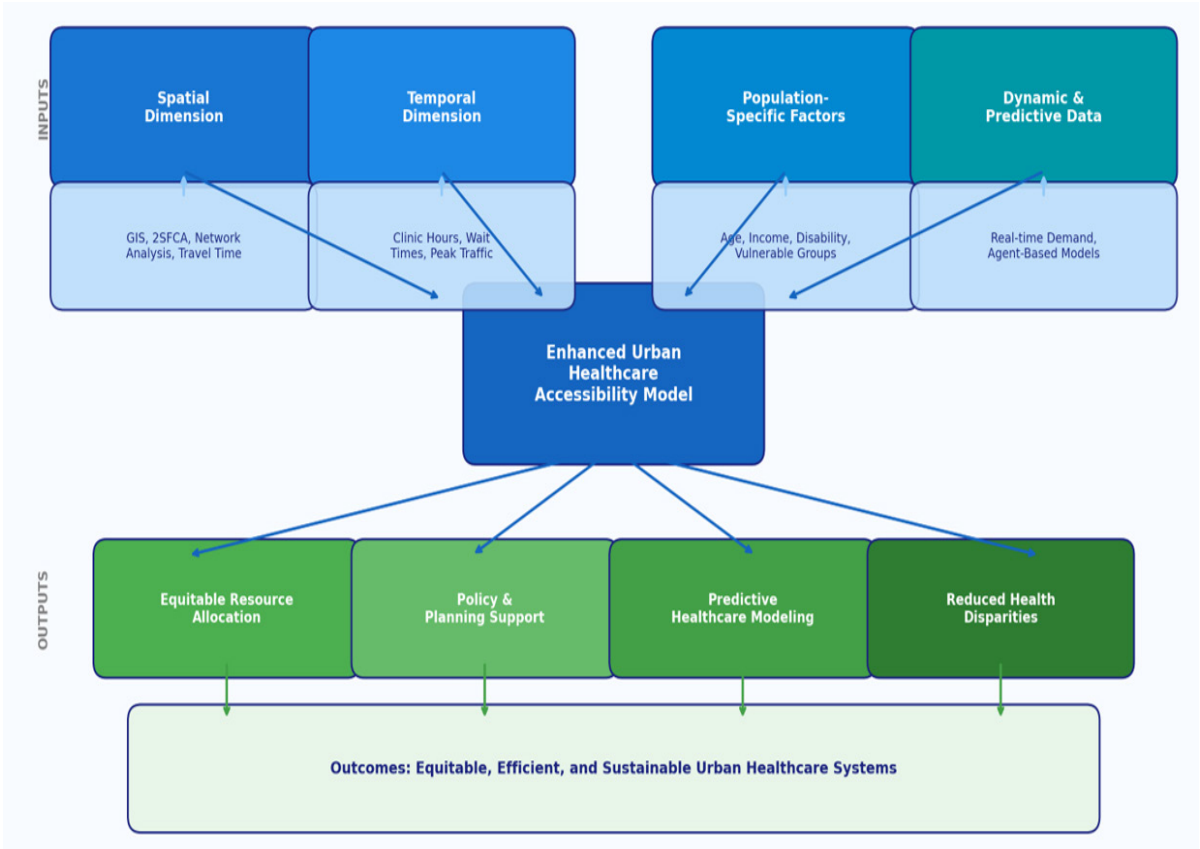


Figure 10: Proposed Integrated Conceptual Framework for Enhanced Urban Healthcare Accessibility.

Proposed Integrated Conceptual Framework

Figure 10 presents the proposed integrated conceptual framework for urban healthcare accessibility. The framework synthesises four input dimensions Spatial Dimension, Temporal Dimension, Population-Specific Factors, and Dynamic & Predictive Data into a central Enhanced Urban Healthcare Accessibility Model. The outputs include equitable resource allocation, evidence-based policy support, predictive modelling capabilities, and reduced health disparities, collectively contributing to equitable, efficient, and sustainable urban healthcare systems.

The framework advances the state of the art by: (1) incorporating advanced FCA variants (2SFCA, E2SFCA, BFCA, 2SVCA) to address spatial dimensions; (2) integrating real-time temporal data including clinic hours, peak traffic, and seasonal demand; (3) embedding population-specific equity metrics for vulnerable groups; and (4) enabling dynamic and predictive simulation through agent-based and mathematical modelling.

CONCLUSION

This systematic review provides a comprehensive synthesis of methodologies used to assess urban healthcare accessibility by critically examining 66 peer-reviewed studies published between 2016 and 2026. The review demonstrates that healthcare accessibility assessment has evolved substantially from conventional distance-based measures to sophisticated GIS-enabled, network-based, and optimisation-driven approaches, with the Two-Step Floating Catchment Area (2SFCA) family and its variants remaining the most widely adopted methodologies. At the same time, recent advances in multicriteria decision analysis, location-allocation modelling, telehealth accessibility assessment, artificial intelligence, and machine learning have expanded the analytical capabilities available for evaluating complex urban healthcare systems.

This study makes four principal contributions to the existing literature. First, it presents a systematic classification and critical comparison of contemporary healthcare accessibility methodologies, highlighting their theoretical foundations, methodological evolution, strengths, and limitations. Second, it identifies several persistent research gaps, including the limited incorporation of temporal dynamics, multimodal transportation systems, behavioural responses, demographic heterogeneity, and real-time urban data into existing accessibility models. Third, the review provides insights into global research trends, demonstrating that China and the United States have emerged as the leading contributors to methodological developments in healthcare accessibility, while highlighting the need for greater evidence from rapidly urbanizing low- and middle-income countries. Finally, the study proposes an integrated conceptual framework that combines spatial, temporal, demographic, transportation, and technological dimensions to support more comprehensive and adaptive healthcare accessibility assessment.

The proposed framework offers practical value for urban planners, healthcare administrators, and policymakers by providing a flexible decision-support tool for healthcare infrastructure planning, resource allocation, service optimisation, and equity-oriented policy development. By integrating GIS, multicriteria decision analysis, artificial intelligence, predictive analytics, and dynamic transportation information, the framework facilitates more responsive and evidence-based planning capable of addressing the evolving healthcare needs of diverse urban populations. Furthermore, incorporating first- and last-mile accessibility, multimodal mobility, and population-specific characteristics enables a more equitable assessment of healthcare access, particularly for older adults, persons with disabilities, low-income households, and other vulnerable groups.

Future research should prioritise the empirical validation of the proposed framework using real-world healthcare, transportation, and mobility datasets across diverse urban contexts. Particular attention should be given to integrating real-time traffic information, clinic operating schedules, patient waiting times, electronic health records, and multimodal travel behaviour into dynamic accessibility models. Advances in artificial intelligence, machine learning, digital twins, and spatial big data analytics also present significant opportunities for developing predictive healthcare accessibility models capable of supporting proactive urban health planning. Such interdisciplinary approaches will contribute to the development of more resilient, equitable, and sustainable healthcare systems that are better equipped to respond to the challenges of rapid urbanization, demographic change, and future public health emergencies.

ABBREVIATIONS

2SFCA: Two-Step Floating Catchment Area; **E2SFCA:** Enhanced Two-Step Floating Catchment Area; **O2SFCA:** Optimised Two-Step Floating Catchment Area; **M2SFCA:** Modified Two-Step Floating Catchment Area; **BFCA:** Balanced Floating Catchment Area; **FCA:** Floating Catchment Area; **GIS:** Geographic Information Systems; **MCDA:** Multicriteria Decision Analysis; **AHP:** Analytic Hierarchy Process; **PCA:** Principal Component Analysis; **PRISMA:** Preferred Reporting Items for Systematic Reviews and Meta-Analyses; **AI:** Artificial Intelligence; **SAM:** Spatial Accessibility Method; **COVID-19:** Coronavirus Disease 2019.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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