

Article

Bibliometric Insights into the Implications of Urban Built Environment on Travel Behavior

Chao Gao ¹ , Xinyi Lai ^{2,*}, Shasha Li ³, Zhiwei Cui ¹ and Zhiyou Long ¹ 

¹ College of Transportation Engineering, Chang'an University, Xi'an 710061, China; 2018023004@chd.edu.cn (C.G.); 2021034002@chd.edu.cn (Z.C.); 2020234028@chd.edu.cn (Z.L.)

² School of Architecture and Planning, Anhui Jianzhu University, Hefei 230601, China

³ School of Humanities, Chang'an University, Xi'an 710061, China; lishasha@chd.edu.cn

* Correspondence: xinyi@stu.ahjzu.edu.cn; Tel.: +86-180-9054-9778

Abstract: With the rapid pace of global urbanization, understanding the impact of the urban built environment on travel behavior has become increasingly significant for developing sustainable and efficient transportation systems. This study conducts a bibliometric review of related research over the past two decades (1997–2023), utilizing 1745 publications from the Web of Science database through network analysis and content analysis. It provides a comprehensive quantitative analysis encompassing publication trends, national and institutional collaborations, and keyword evolution clustering perspectives. The results reveal that (1) academic interest in exploring the implications of the urban built environment on travel behavior has grown markedly, especially in the past decade, with emerging technological approaches and research perspectives; (2) the USA, P.R.CHINA, and the United Kingdom are major research forces in this field, with notable contributions from research institutions in P.R.CHINA and the USA; (3) the “Transportation Research Part” series journals demonstrate extensive influence both in terms of publication count and citation count; (4) through keyword co-occurrence network analysis, three development stages along with five major clusters were identified: travel behavior modeling and public health, active transportation and sustainable development, urban development and carbon emissions, land use and transportation integration, and urban transportation systems and machine learning. Overall, sustained research remains warranted within this field, particularly focusing on selecting new built environment metrics while integrating emerging technologies into travel behavior modeling frameworks. The insights from this study have implications for urban transportation planning and policy, offering guidance on future research directions and policymaking.

Keywords: urban built environment; travel behavior; bibliometric analysis; land use and transportation integration; active transportation; sustainable transportation systems



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1. Introduction

Rapid global urbanization has resulted in imbalanced development in many cities, with population growth outpacing land development. This disparity between urbanization and urban expansion has created numerous issues that severely hinder sustainable urban growth, including traffic congestion, air pollution, and declining quality of life. To address these challenges, urban planners worldwide have proposed and implemented various sustainable transportation strategies. For instance, the USA has introduced “New Urbanism” and “Transit-Oriented Development”, Europe promotes the “Compact City” model, while China focuses on its “Transit Metropolis” strategy. These approaches all emphasize guiding urban expansion through increased density, mixed land use, and improved public transit access [1]. Their objectives are to revolutionize green transportation by encouraging public and nonmotorized transit options while reducing reliance on private vehicles.

A crucial aspect of these sustainable policies involves leveraging principles of urban built environment (UBE) planning to shape spatial development in ways that foster livable communities and cityscapes conducive to low-carbon mobility transitions. The UBE comprises an interconnected spatial structure shaped by three pivotal elements: land use, urban design, and transportation systems [2]. Land use pertains to the spatial distribution and zoning of various activities, such as residential areas, commercial districts, and industrial zones within urban localities. Urban design encompasses the layout, aesthetics, and functionality of urban components, including streetscapes and public spaces. Transportation systems encompass provision along with service quality for diverse modes like sidewalks, public transit networks, and bike lanes. The measurement framework of the UBE has evolved over time. Initially, Robert Cervero's "3Ds" model—density, diversity, and design—was widely adopted [3]. However, this has evolved into a more comprehensive framework that encompasses destination accessibility, distance to transit, demand management, and demographics. In essence, the interplay between land use, urban design, and transportation systems not only shapes the urban spatial form but also significantly influences sustainable urban development strategies and the choice of residents for greener mobility options.

Understanding how the UBE shapes sustainable travel behavior is increasingly significant as cities worldwide undergo spatial restructuring for low-carbon transitions. This paper conducts a bibliometric analysis to assess the state and evolution of the research on the UBE implications for travel behavior from 1997 to 2023 by examining trends in publications, collaborations between institutions and nations, key journal influence, and emerging research themes.

This paper is organized as follows. Section 2 introduces the methodology. Section 3 presents findings related to publication and citation trends, collaborative networks between nations and institutions, key journals, and keyword evolution clustering. Section 4 discusses implications and future work. Finally, Section 5 summarizes the main findings and conclusions.

2. Materials and Methods

2.1. Bibliometric Method

In order to achieve our research objectives of comprehending the implications of the UBE on travel behavior, this study employs bibliometric analysis techniques. Bibliometric analysis is a quantitative method utilized for analyzing academic publications. It encompasses citation analysis and content analysis, providing a means to identify interconnections of knowledge and ascertain current research trends within a field of study. A key component of bibliometric analysis is citation network analysis, which reveals the relationships between cited and citing papers, as well as interactions among researchers. This method enables the visualization of interconnections between subfields and the intellectual developments within a research area [4]. For instance, in the context of a citation network graph, each node represents a publication. The size of the node signifies the academic influence of the publication, which is gauged by its number of citations received. Links between nodes indicate direct citation flows between corresponding papers. The position of a node within the graph is determined by its connections with other publications, and arranged using algorithms such as force-directed layouts, where nodes sharing more links are placed closer together. Lastly, modularity-based algorithms are employed to detect clusters or communities within the graph [5].

Furthermore, content analysis typically follows citation analysis to identify current hot topics based on keyword frequency and distributions. In this study, citation and content analysis were conducted to determine knowledge networks and research trends in the UBE and travel behavior. Citation analysis depicted citation networks and clusters revealing influential works along with their authors' contributions. Content analysis identified popular topics, leading journals, and active institutions involved in these areas. Together, these analyses provided an extensive understanding of research prospects and

directions. Finally, to visualize the citation networks and clusters, VOSviewer 1.6.19 [6] and Bibliometrix 1.1 [7] software were used to detect influential research and authors and their connections. The visualization of citation networks and evolution clustering offered insights into the evolution and current state of research in this domain.

2.2. Data Collection Criteria

Based on the search query (TS = (“Urban Built Environment” OR “Urban Form” OR “Urban Design” OR “Built Environment”) AND TS = (“Travel Behavior” OR “Transportation Mode” OR “Travel Mode” OR “Travel Pattern” OR “Transportation Choice” OR “Travel Choice”)), a total of 1745 publications were retrieved from the Web of Science database. Among these publications, journal papers accounted for 85.50%, followed by conference papers at 4.07%, review papers at 4.29%, and other publication types like books and reports at 6.13%. The publications spanned the period from 1997 to 2023, originating from a diverse range of sources (322 in total). The annual growth rate of 21.22% indicates a significant recent increase in research activity within this field. With an average publication age of 4.08 years, it is evident that this is an emerging research area with ongoing interest and relevance. The average citation count per publication stands at an impressive figure of 18.99, highlighting the considerable academic attention and recognition received by these studies thus far. Furthermore, the extensive use of references (52,841) demonstrates both the depth and breadth of the literature utilized in this field as well as its well-established nature.

In conclusion, based on bibliometric analysis conducted using data retrieved from the Web of Science database, it can be inferred that research pertaining to the implications of the UBE on travel behavior represents a rapidly growing field with established foundations. The high percentage representation of journal papers coupled with robust citation rates attests to its quality and impact within academia while also indicating its relevance to scholarly discourse overall. Moreover, given the substantial number of references employed across these publications, it becomes apparent that the existing literature has been extensively drawn upon, thereby contributing to a rich body of knowledge associated with this domain.

2.3. Research Flow

The research process of this systematic literature review adheres to rigorous protocols and can be delineated into five distinct phases: identification, screening, eligibility, inclusion, and bibliometric analysis, as shown in Figure 1. The research flow aligns with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [8]. The systematic search aims to be comprehensive, reproducible, and transparent. Each phase applies pre-defined criteria to focus on English language peer-reviewed academic publications within a specified date range. Detailed descriptions of the procedures undertaken in each phase are provided below. Documenting the literature search and selection steps promotes methodological consistency and integrity. Structured abstraction and synthesis of data sources then facilitates evidence-based responses to the guiding research questions. Regular updates will incorporate high-quality new studies to maintain a dynamic and current representation of the literature.

Initiating the research process involved conducting an extensive search in the Web of Science database which yielded a substantial collection of 1745 publications. To refine this vast pool, a thematic approach was employed focusing on exploring the intricate relationship between the UBE and travel behaviors. This methodological refinement led to shortlisting 1489 publications that closely resonated with this study’s core objectives.

The subsequent phase involved meticulous screening where careful scrutiny was applied to evaluate the titles of these publications. This step played a pivotal role in eliminating duplicates as well as conference proceedings or book sections, ensuring dataset purity. Following this rigorous screening process, the collection was narrowed down further, resulting in 1391 pertinent publications.

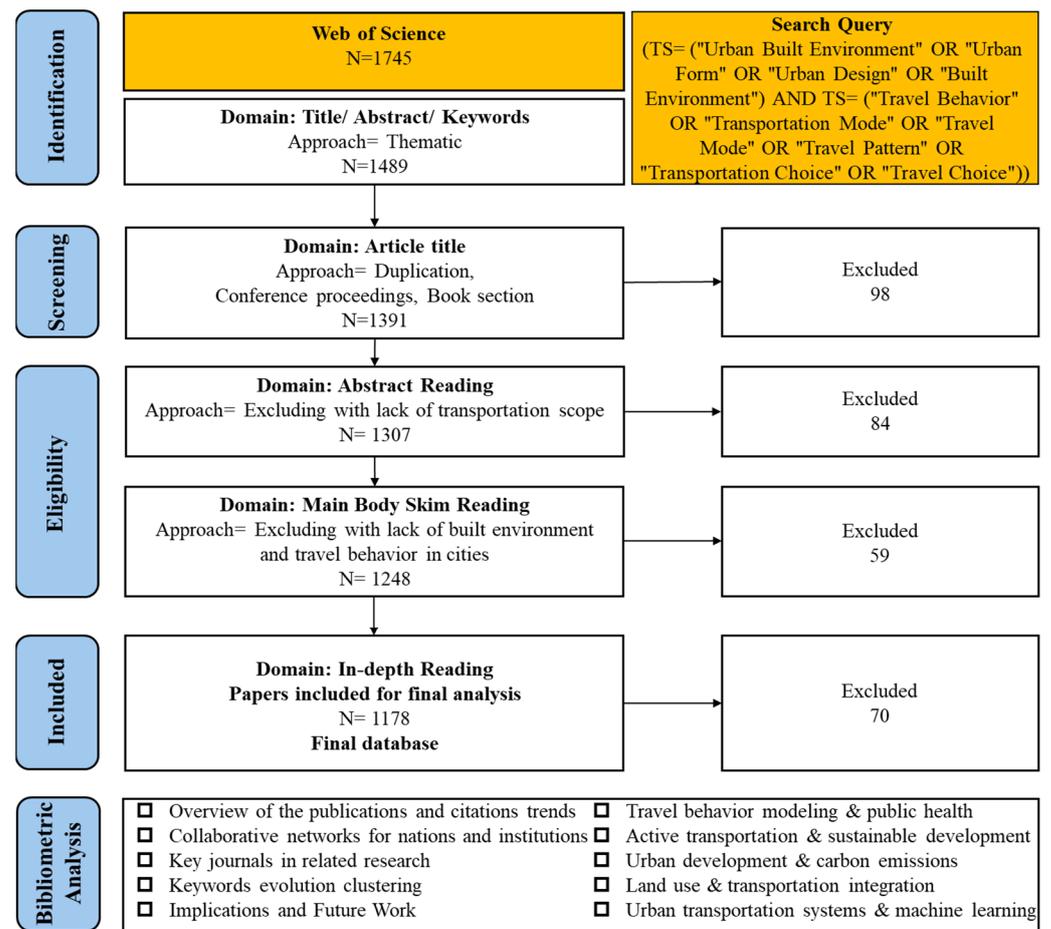


Figure 1. Research workflow.

Delving deeper into the eligibility criteria, a two-tiered approach was adopted. The first tier involved a thorough perusal of abstracts, ensuring each publication was anchored in the transportation domain. This criterion further whittled down the list to 1307 publications. The second tier demanded a cursory reading of the main body, emphasizing papers that intricately discussed the UBE’s implications on travel behaviors within cities. This rigorous process resulted in a distilled list of 1248 publications.

To ensure the utmost relevance and quality of the selected publications, comprehensive in-depth reading was conducted. This phase played a crucial role in discerning the nuances and significance of each publication, resulting in the selection of 1178 papers that were essential to achieving this study’s objectives and were thus incorporated into the final database for a more granulated analysis.

The final analysis went beyond a quantitative overview by delving into qualitative aspects such as publication and citation trends, collaborative networks among nations and institutions, key journals, and evolution clustering of keywords. The profound insights gained from this analysis not only illuminated the current research landscape but also paved the way for identifying implications and charting avenues for future endeavors in this domain.

3. Results

3.1. Overview of the Publications and Citations Trends

Figure 2 shows the research field investigating the UBE implications for travel behavior has undergone significant publication and citation changes over the past few decades. From 1997–2009, related research was relatively scarce, with 0–5 papers published annually.

However, since 2010, related research has accelerated rapidly, with annual publications increasing almost 150 times compared to 2009, nearing 300 papers by 2023.

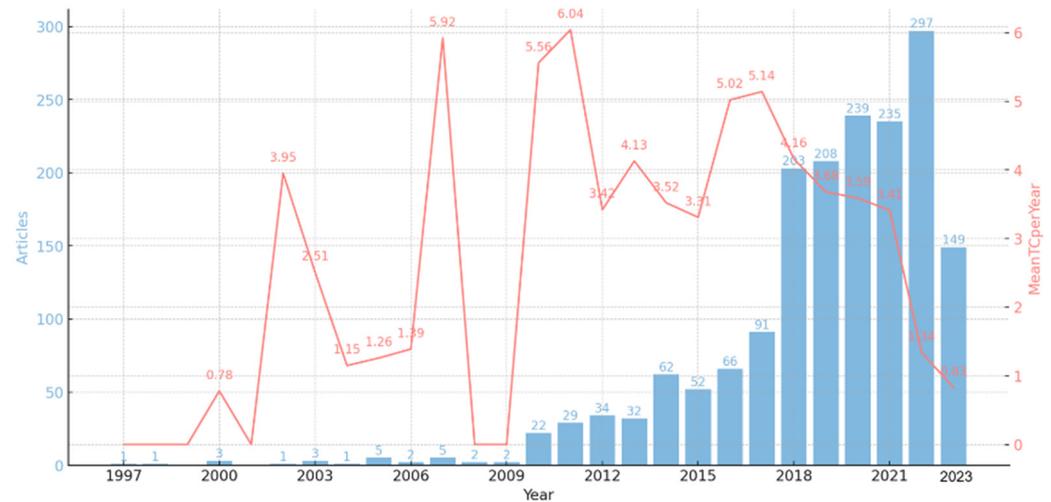


Figure 2. The number of related publications and annual average citations from 1997 to 2023.

This exponential growth reflects increasing awareness of the urban development and transportation planning impacts on residents' lives, as well as advancing research techniques enabling more studies. Additionally, annual average citation counts have fluctuated during this period, potentially reflecting different research stages. In the early stage (1997–2002), the publication volume was low but annual average citation counts reached one of the higher levels during the 1997–2023 period analyzed. As the field expanded after 2010, the number of publications surged while the per paper citation rate exhibited a slight decreasing trend in recent years. This may relate to a time lag between when publications are published versus when they accumulate the most citations.

However, the total citations, calculated from the annual publication volume multiplied by the annual average citations per paper, have still been rising overall. This suggests that cumulative attention and recognition for this research area continues to grow over time, despite the decline in the per paper citation rate.

These data reflect the development trend of the research field investigating the implications of the UBE on travel behavior and the degree of research activity, indicating the significant value of related study for our understanding and improvement of urban life. In future research, researchers should further improve the quality and impact of their studies to obtain more citations and promote the development of this field.

3.2. Collaborative Networks for Nations and Institutions

Figure 3a illustrates the research contributions of various nations in the field of the UBE and its implications on travel behavior, measured by the number of publications, total citations, and average citations per paper. The USA leads with 583 publications, 14,420 total citations, and 24.73 average citations per paper, highlighting its pioneering role. P.R. CHINA has also made significant contributions with 496 publications, 7768 total citations, and 15.66 average citations per paper, demonstrating its growing influence. Similarly, the United Kingdom contributed substantially with 138 publications, 3400 total citations, and 24.64 average citations per paper. Although with fewer publications, Greece (7) and Brazil (17) have over 40 average citations per paper, indicating high-impact research. Other nations like New Zealand, Belgium, Netherlands, Germany, and Spain have also made valuable contributions, providing rich data and insights.

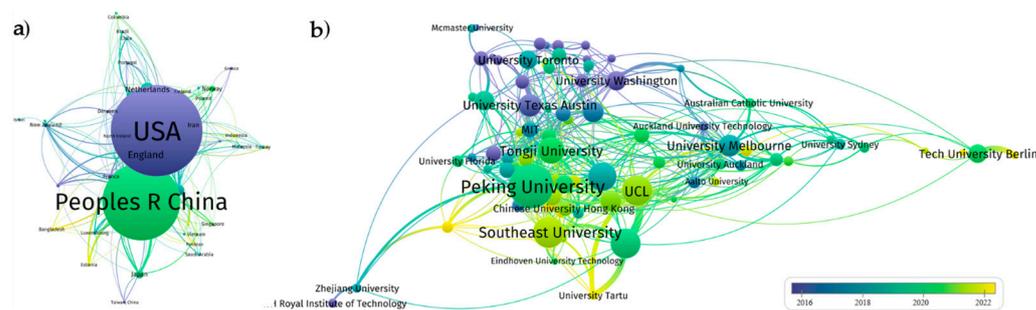


Figure 3. Evolution collaborative networks among (a) nations and (b) institutions in the related field from 1997 to 2023.

Furthermore, Figure 3b displays bibliometric insights into the UBE implications for travel behavior by clustering collaborating institutions. Cluster 1 contains the University of Washington and University of Texas at Austin, showing close early collaboration on the built environment and travel behavior with shared research themes, methods, and data. Texas published 33 papers with 839 total citations and 25.42 average citations. Washington published 28 papers with 1928 total citations and 68.86 average citations, indicating significant contributions and implications. Cluster 2 includes University College London (UCL) and Ghent University, reflecting England–Belgium collaboration. UCL published 44 papers with 1026 total citations and 23.32 average citations. Ghent published 43 papers with 1394 total citations and 32.42 average citations, demonstrating substantial contributions. Cluster 3 consists of Peking University, Tongji University, and the University of Hong Kong, suggesting close China-based collaboration. Hong Kong published 41 papers with 825 total citations and 20.12 average citations. Tongji published 39 papers with 652 total citations and 16.72 average citations. Peking published 64 papers with 1627 total citations and 25.42 average citations, reflecting their extensive recent research. Overall, the contributions of these major research nations and institutions have significantly advanced our understanding of the relationship between the UBE and travel behavior. However, there is still much to be explored in this field, and greater collaboration between nations and institutions could lead to more comprehensive insights.

3.3. Key Journals in Related Research

The number of papers published and citations received indicate a journal's impact. In research on the UBE implications for travel behavior, the Transportation Research Part series have high publication and citation counts, as seen in Figure 4, demonstrating broad influence. Transportation Research Part A—Policy and Practice has 108 papers and 3671 total citations, while Transportation Research Part D—Transport and Environment has 108 papers and 3425 total citations. Additionally, Transportation Research Record has 107 papers and 1567 total citations, showing a significant impact on the UBE and travel behavior research. In contrast, Sustainable Cities and Society has just 12 papers and 59 total citations, suggesting more limited publications and impact despite relevance.

A journal's average publication year reflects its history. Longer established journals like Transportation Planning and Technology, with a 2016 average publication year, have more extensive experience in this field. In contrast, newer journals like Journal of Transport and Land Use, with a 2021.08 average, may have deeper emerging topic expertise. Average citation count indicates typical journal article impact. The International Journal of Behavioral Nutrition and Physical Activity has a high 82.68 average citation count, suggesting its papers generally receive greater attention and influence, potentially reflecting a higher academic quality and impact.

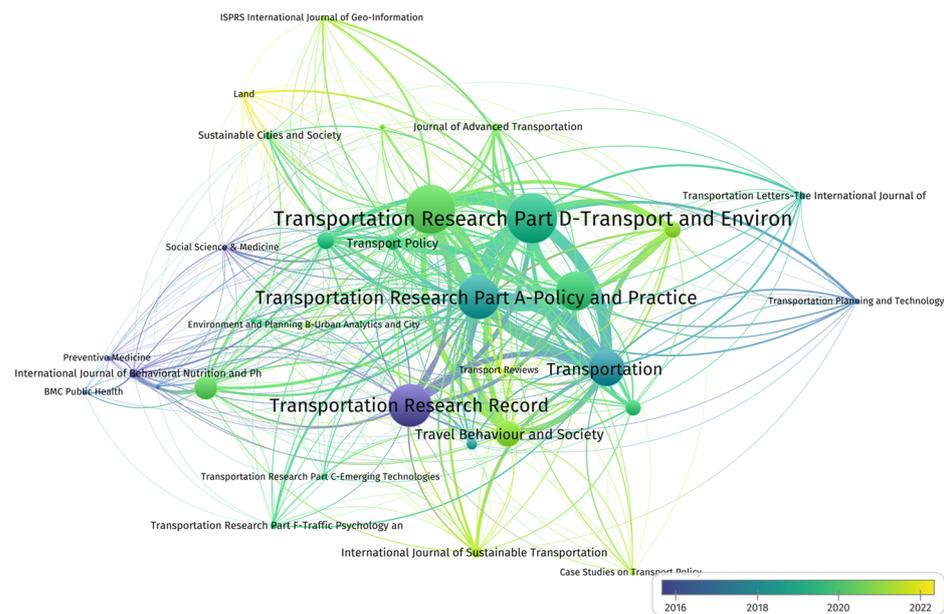


Figure 4. Key journals in related research from 1997 to 2023.

It should be noted that academic journals have varying publication frequencies and acceptance rates. From a relative perspective, some journals may publish more frequently on the topics discussed by the authors. Therefore, when analyzing prominent journals, researchers could consider the proportion of topically related papers compared to total journal publications, to better gauge each journal's relative emphasis. Take *Transportation Research Part D*, for example. It published approximately 500 papers during 2015–2023, among which 35 (7% of total) were related to the UBE influencing travel behavior. In contrast, although *Sustainable Cities and Society* published only 29 related papers, given its lower overall output, the proportion of relevant papers is higher. Incorporating this relative metric enables a more accurate assessment of each journal's attention and contribution to a research area.

Additionally, each journal's impact relates to its topical scope. For instance, *Transportation Research Part A* focuses on transportation policy and planning, hence its related papers have high citation counts, reflecting this field's importance. Emerging journals like *Journal of Transport and Land Use* cover novel intersections, so understandably their related papers have relatively fewer citations as they explore new territory. Comprehensively evaluating journals' priorities, history, and scope facilitates holistic understanding of their contributions.

Overall, these data provide an in-depth understanding of key journals in UBE and travel behavior research. This can assist researchers in selecting appropriate publication venues and help researchers and policymakers understand research evolution and trends in this field.

3.4. Keyword Evolution Clustering

Figure 5a presents the keyword evolution clustering results, tracking occurrence, peak research, and recent years for the top 20 keywords in UBE and travel behavior research. The top-ranked keyword, "built environment," has been the most frequent since 2012, with 787 total occurrences. The second-ranked, "travel behavior", has also seen extensive attention, with 596 occurrences since its first appearance in 2013. Other recent focus areas include "land use" (ranked third with 404 occurrences), "physical activity" (fourth with 353 occurrences), and "urban form" (fifth with 351 occurrences). This evolution indicates a shift from built environment physical features to understanding how land use, urban form, and activity patterns influence travel behavior. The emergence of "walking" (sixth with 292 occurrences) highlights the growing importance of active

transportation modes like walking and cycling to reduce vehicle use. The 2021 appearance of “COVID-19” (sixteenth with 21 occurrences) reflects the pandemic’s impact on research by accelerating remote work and virtual meetings with potential long-term effects. Other notable keywords are “machine learning” (eleventh with 34 occurrences) and “decision tree boosting” (fifteenth with 24 occurrences), indicating the increasing use of data analysis and machine-learning techniques [9].

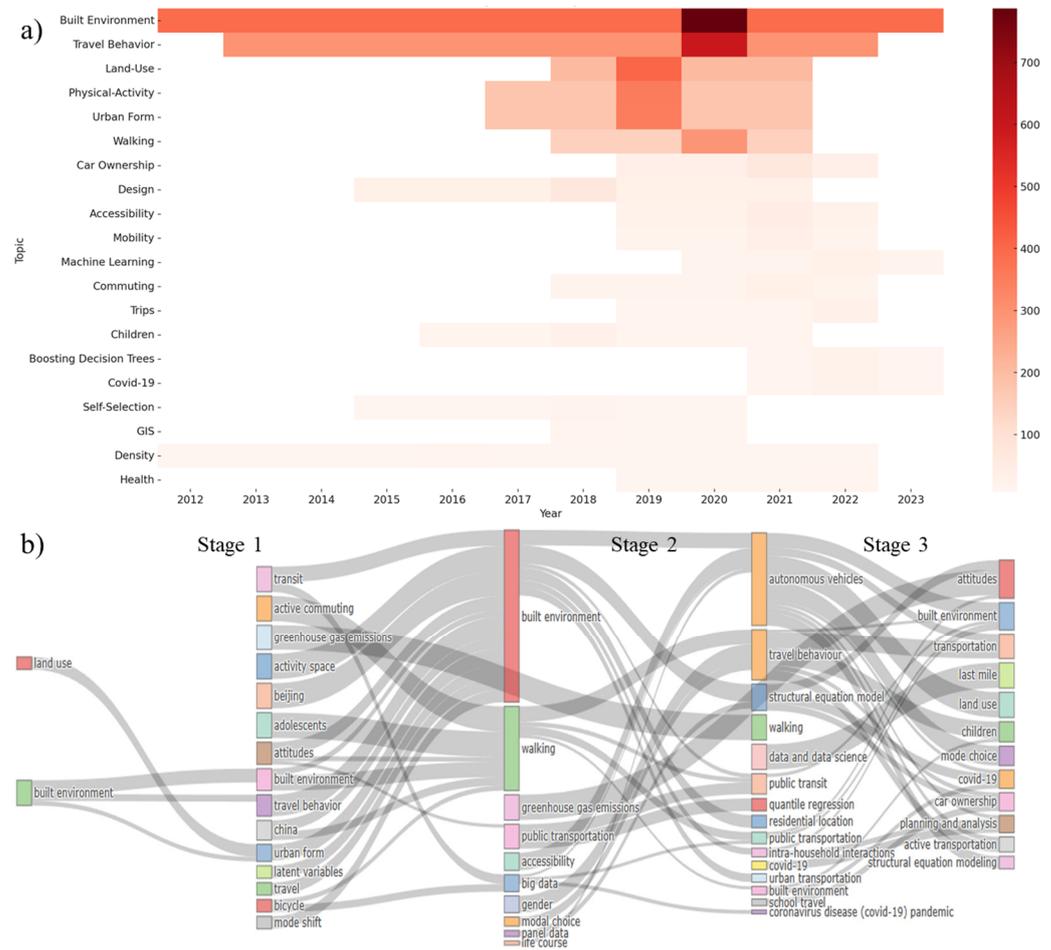


Figure 5. Keyword evolution clustering based on (a) keywords and (b) keywords plus from 1997 to 2023.

Keywords Plus is a feature of Web of Science that extends keyword analysis beyond author-assigned terms. It identifies frequently co-occurring words in article titles, which may not be included in the keywords provided by authors. This enables a more nuanced and comprehensive representation of article content. Figure 5b presents an overview of keyword evolution clustering using Keywords Plus in the field of UBE and travel behavior research. During the theoretical framework formation stage (1990s–2015), research prior to 2012 primarily focused on traditional land use and built environments, reflecting slower urbanization and limited planning diversity. The aim was to enhance traditional environments and transportation for sustainability and improved quality of life. Between 2013 and 2015, rapid urbanization led to innovative planning practices, shifting researchers’ focus toward urban morphology, built environments, public transit, active commuting, emissions, activity spaces, Beijing, adolescents’ attitudes in China, as well as latent variables. These keywords indicate a growing interest in emerging urbanization issues such as the influence of urban form on travel behavior, the role of public transit in promoting sustainability, and understanding attitudes and behaviors among adolescent populations. In summary, the intrinsic demands posed by rapid urban evolution along with changes

in external factors collectively drive a shift in research perspectives within this rapidly evolving field.

From 2015 to 2018, as the urbanization process deepened in the empirical studies accumulation stage, urban transportation and development faced new challenges and opportunities. Consequently, the emphasis of keywords shifted toward walking, greenhouse gas emissions, public transportation, accessibility, big data, gender, mode choice, panel data, and lifecycle. These keywords reflected researchers' in-depth exploration of urban transportation and development, including the implications of the built environment on travel behavior, the sustainability and efficiency of walking and public transportation, and the role of big data in urban planning and transportation management.

In contrast, as research entered the systematic summary of empirical studies stage (2018–present), from 2019 to 2021, research focused on autonomous vehicles, travel behavior, structural equation modeling, walking, data and data science, public transportation, quantile regression, residential location, intra-household interactions, the COVID-19 pandemic, urban transportation, and campus travel. This shift in focus can be attributed to the further acceleration of the urbanization process during this stage, coupled with the global challenges posed by the COVID-19 pandemic in urban transportation and development. After 2022, the research focus shifted toward attitudes, last-mile connectivity, children, mode choice, COVID-19, planning and analysis, and active transportation. This shift can be inferred from the relative maturity of urbanization, urban planning, and development processes. Researchers began to pay greater attention to practical details like the influence of attitudes on travel behavior, the impact of the built environment on children's travel and health, and strategies to address last-mile connectivity challenges. Additionally, the profound impact of the pandemic prompted research on effects and mitigation measures like pandemic-era planning, management, travel behavior, and mode choice.

In conclusion, research themes in the UBE and travel behavior have closely paralleled urbanization, planning, and development dynamics. As urbanization accelerated and planning practices diversified, research shifted from traditional land use and built environments to emerging topics like urban morphology, public transit, emissions, and data science. The COVID-19 pandemic further highlighted the need to examine its impacts on urban transportation and development. This led researchers to focus on issues including autonomous vehicles, travel behavior, and pandemic-responsive planning. The evolution of keywords and research interests reflects researchers' continuous efforts to advance knowledge and provide insights to address changing realities in urban planning, transportation, and development.

4. Implications and Future Work

This study utilized VOSviewer software to conduct a clustering analysis of publications based on the frequency of text terms appearing in titles, abstracts, and keywords. After optimizing the parameters, the final clustering configuration achieved an aggregation of papers into groups by research theme. Specifically, the clustering relied on text mining and natural language processing to identify latent semantic connections between publications [10].

By mapping together papers with similar terminology usage patterns, the analysis depicted thematic groups that minimized differences within clusters. A total of 1178 selected papers provided 3619 keywords, with the citation network shown in Figure 6. The nodes represent keywords, with the node size indicating the keyword frequency. Only keywords cited over 50 times are displayed. The links between nodes represent direct citation flows between two keywords. The papers are grouped into five clusters, each represented by a dashed ellipse. These findings indicate that the implications of the UBE on travel behavior are a complex and multifaceted field requiring interdisciplinary research approaches for in-depth exploration. The following sections will examine this in detail from five perspectives as follows:

reduce automobile usage. Perceptions of safety and exposure to air pollution are crucial factors affecting travel behavior. Unraveling the relationship between travel behavior and air pollution exposure can inform interventions that promote active transportation while minimizing exposure to harmful pollutants. The intention to engage in certain behaviors, as highlighted in planned behavior models, is another critical concept that can guide the design of interventions. Urban design and infrastructure play an indispensable role in encouraging active transportation and walkability. Neighborhood walkability is a significant determinant of active transportation.

These studies offer invaluable theoretical and practical insights, and they simultaneously uncover numerous avenues for future research. These include gaining a profound understanding of walking and cycling behavior patterns, considering more potential influencers of travel behavior, and conducting research utilizing contemporary data science methodologies. Therefore, by delving deeper into travel behavior modeling, we can better understand the factors affecting travel behavior, and propose effective interventions to promote active transportation and improve public health outcomes.

4.2. Active Transportation and Sustainable Development

Cluster 2 is also an important research area focusing on promoting sustainable urban development through active modes of travel. It covers multiple topics including optimizing the pedestrian environment and the impact of urban morphology on emissions. In this cluster, Wong et al. [17] conducted a systematic review on GIS-measured environmental correlates of active school transport, providing a nuanced understanding of how the built environment influences children's travel behaviors. Similarly, Karmeniemi et al. [18] performed a systematic review of longitudinal studies and natural experiments exploring the built environment's role as a determinant of physical activity, highlighting the complex interplay of physical surroundings on mobility patterns.

The core of this cluster is promoting active transportation modes such as walking and bicycling to reduce automobile use and foster sustainable mobility [19]. Active modes are more sustainable, affordable, and healthy compared to automobile travel, helping reduce greenhouse gas emissions, air pollution, and traffic congestion. The UBE significantly influences active travel behavior, including residential location, accessibility, and availability of pedestrian and bicycle infrastructure. Policies and plans promoting active and sustainable transportation help create more equitable and sustainable communities, especially in auto-dependent urban areas. The COVID-19 pandemic has underscored the importance of sustainable and resilient transportation systems that can adapt to changing environments while supporting public health and safety. The pandemic has led to calls for greater investment in active transportation infrastructure and policies supporting sustainable mobility. Equity is a key issue as transportation policies and infrastructure can significantly impact disadvantaged and marginalized communities. Policies and plans promoting sustainable mobility and active transportation must be designed equitably to avoid exacerbating existing social and economic disparities.

Overall, research topics in cluster 2 include travel behavior, mode choice, satisfaction, and factors associated with different transport modes. Researchers use surveys, experiments, observational studies, and other methods to understand factors influencing travel behavior and promoting sustainable transportation. "Active transportation & sustainable development" is an important research and policy area, as sustainable and equitable transportation systems are critical for sustainable development and improving community health and well-being worldwide.

4.3. Urban Development and Carbon Emissions

Cluster 3 is a critical research area examining the relationship between urbanization, land use, transportation systems, and greenhouse gas emissions. Rapid urbanization and motorization in cities worldwide have led to surging carbon emissions, underscoring the

need to develop sustainable, low-carbon urban models. This research cluster analyzes the carbon impacts of various urban development patterns and transportation policies.

Urban development and carbon emissions comprise a set of closely related keywords critical for understanding the dynamics of urbanization, the impacts of urbanization on the environment, and the role of urban design and planning in reducing greenhouse gas (GHG) emissions. Apart from urban form, the ownership and consumption patterns of urban residents also impact carbon emissions. A shift toward sustainable consumption and lifestyles can substantially reduce a city's carbon footprint. Similarly, employment patterns and commuting behaviors, such as telecommuting and flexible work arrangements, can decelerate travel demand and associated emissions.

Two pivotal studies, including Hankey's research [20], focused specifically on how the shape and structure of urban environments' urban form impact GHG emissions from passenger vehicles in the USA. Their conclusions underscore the importance of urban form in shaping people's travel patterns and, consequently, the total annual vehicle distance traveled, which is a substantial source of urban GHG emissions. The study by Lee [15], on the other hand, explored the influence of urban form on GHG emissions in the USA household sector. Their findings reinforce the idea that urban development is a significant source of GHG emissions and that the design of urban form, including factors such as density, mix of land uses, and building morphology, have profound impacts on energy use, emissions, and travel behavior. In both high-density mixed-use communities and compact built forms with efficient transportation systems, per capita energy use and GHG emissions tend to be lower compared to low-density single-use developments. These sprawling patterns necessitate a greater reliance on automobile travel, leading to higher GHG emissions.

Therefore, effective urban planning and design strategies like compact development, mixed land use, transit-oriented development (TOD), green building design, and sustainable transportation systems can help mitigate the carbon footprint of cities. Integrated, interdisciplinary approaches prioritizing sustainable, low-carbon urban development, coupled with the adoption of renewable energy and energy efficiency technologies, are critical. The keyword clusters highlight the importance of urban development and design in reducing GHG emissions.

4.4. Land Use and Transportation Integration

Land use and transportation integration is an urban design strategy that coalesces transportation infrastructure with land-use patterns. This approach is often linked to TOD, which focuses on public transit and reduces reliance on private vehicles. Key topics in this domain include residential self-selection, auto ownership, and neighborhood design. Residential self-selection involves individuals choosing their dwelling based on factors like proximity to workplaces or amenities, and may be influenced by their preferred mode of transport. TOD is a prevalent strategy in this integration effort, but its success depends on variables like accessibility, affordability, and the availability of alternate transport modes. Auto ownership, often linked to increased traffic and pollution, is a significant aspect. Strategies to lower car ownership include promoting public transit and active travel modes, and incentivizing carpooling and ridesharing. Neighborhood design, emphasizing walkability and mixed-use development, can foster sustainable travel and reduce car dependency. However, the effectiveness of these strategies hinges on factors like transit availability, housing affordability, and resident preferences. Concepts such as causality, choice, self-selection, and preference are essential for analyzing the complex dynamics between land use and transportation.

Cluster 4 is imperative for sustainable urban development. Emerging data sources and analytical techniques can unveil novel insights into travel behavior to inform policymaking. For instance, Kerr et al. [21] discussed utilizing GPS devices to objectively trace locations and physical activity. This enables analyzing the influence of specific land use on associated behaviors. Zhao [22] examined cycling as a transfer mode to metro stations in Beijing

using survey data. They discovered travel distance as the most significant predictor of cycling transfer rates. Land-use diversity, green spaces, and bike-sharing programs around metro stations also promoted cycling transfers. Ibraeva et al. [1] provided a comprehensive review of research on TOD, combining transportation and land-use planning centered on transit hubs. They delineated achievements and challenges across domains such as travel impacts, real estate effects, planning tools, and policy issues. A key gap is elucidating the factors affecting TOD outcomes. Other seminal research includes Chen et al. [23], who explored the potential of big data in travel analysis. Giles-Corti [24] examined the impact of urban design on walking but needs to further consider population differences. Millard-Ball discussed the implications of automated vehicles for cities, but safe utilization remains challenging. Boone-Heinonen et al. [25] investigated relationships between the environment and activity, unveiling the role of residential self-selection, but needs to address population and community diversity. While substantial research exists in this domain, challenges persist regarding data and technology applications, policy translation, and other aspects.

In summary, cluster 4 aimed at creating sustainable, livable communities prioritizing public transit, walking, and cycling. A related set of keywords reflects the complexity and multifaceted nature of the relationship between land use and transportation, encompassing concepts related to mode choice, residential self-selection, neighborhood design, and the environmental, social, and economic impacts of transportation decisions.

4.5. Urban Transportation Systems and Machine Learning

Machine learning (ML) is gaining traction in the domain of urban transportation systems. ML is an approach to train algorithms to discern inherent patterns in data and predict outcomes based on statistical analysis. ML methods are data-driven: they extract meaningful information from data rather than pre-modeling causal relationships. ML algorithms fall into two main categories: supervised learning and unsupervised learning. For supervised learning, neural networks, random forests, support vector machines, gradient boosting decision trees, decision trees, k-nearest neighbors, and logistic regression are the most widely used supervised learning algorithms. Fewer studies combine supervised learning algorithms with cellular automata analysis. Research utilizing only unsupervised learning algorithms (PCA, k-means, DBSCAN, hierarchical clustering, spectral clustering, SOM) is conducted for data selection and k-means clustering.

Machine-learning techniques such as random forests, gradient boosting decision trees, and neural networks are gaining traction in travel behavior research and outperforming traditional statistical models like multinomial logit. Hagenauer [26] compared seven classifiers on Dutch travel survey data and found random forests had the best predictive performance for modeling travel mode choice. These advanced machine-learning methods can also elucidate complex nonlinear relationships between the built environment and travel behavior, which traditional linear regression models cannot capture. For instance, Ding et al. [27] applied gradient boosting to examine the nonlinear effects of the built environment on driving distance in Oslo. They discovered salient nonlinear effects challenging the common linearity assumption. Cheng et al. [9] demonstrated the usefulness of random forests for travel mode choice prediction using survey data from Nanjing, China. The random forest model was significantly more accurate than multinomial logit and could estimate the relative importance of variables automatically. Similarly, Yang et al. [28] adopted random forests to uncover the nonlinear effects of streetscape greenery on the walking propensity of older adults in Hong Kong. They confirmed streetscape greenery has a positive effect on walking within a certain range, but the association diminishes outside that range.

Advanced machine-learning techniques such as random forests and gradient boosting trees are gaining popularity in travel behavior research owing to their superior predictive performance over traditional models. A key advantage is their capacity to model complex nonlinear relationships and automatically determine relative variable importance.

Overall, accurately elucidating the complex relationship between the UBE and travel behavior necessitates an interdisciplinary research paradigm. While extant research has established a robust theoretical foundation, further in-depth inquiry is still required to obtain a more comprehensive and precise understanding. This can be achieved by enhancing research methods, expanding the scope of variables, constructing hybrid models, enlarging result validation, and strengthening model application. Therefore, future work should concentrate on methodological innovation, model optimization, empirical expansion, and cross-disciplinary integration. Advanced data analysis techniques should be leveraged to refine the selection and measurement of UBE variables to boost model accuracy. Additionally, hybrid modeling approaches integrating the strengths of linear, nonlinear, and machine-learning models could be explored. Model applicability should also be enhanced to provide decision support, and more influencing factors should be considered to develop holistic models. Finally, multidisciplinary collaboration utilizing an integrative research framework should be reinforced. In summary, continuously advancing the comprehension of complex problems necessitates the systematic promotion of synergistic innovation across methods, models, data, and applications.

5. Conclusions

Through bibliometric analysis, this study systematically reviews and summarizes relevant research over the past 20 years on the implications of the UBE for travel behavior. The findings indicate sustained growth in academic interest in this field, with new technological approaches and perspectives continuously surfacing. Despite global research coverage, empirical investigations concentrate more on developed nations, reflecting how data availability constraints still guide research trajectories. While this review synthesizes the breadth of the current literature, some limitations provide opportunities for additional investigation. In particular, more primary data collection is needed in developing country contexts, where data scarcity has constrained localized analyses. Furthermore, the predominance of cross-sectional research designs limits understanding of longitudinal impacts over time. Overcoming methodological constraints related to data availability and study design would enable more robust analyses of UBE interventions across geographic and economic contexts.

However, some limitations should be acknowledged. This study relies solely on the Web of Science database for literature retrieval, restricting analytical dimensions. Future research could expand bibliographic databases and apply multidimensional analytical techniques to enhance the systematic investigation. For instance, incorporating Scopus or Chinese databases like CNKI would mitigate database biases and enable comparisons across sources. Nonetheless, this study delineates developmental stages and research hotspots, highlights major contributions from institutions in countries like the USA, P.R. CHINA, and the United Kingdom, and indicates the leading position of the “Transportation Research Part” series journals, providing relatively reliable and comprehensive background knowledge on disciplinary evolution for scholars. More importantly, the keyword co-occurrence network analysis identifies four developmental phases and five major research clusters, assisting researchers in determining priorities and trajectories based on this evolutionary path.

By offering valuable insights for urban transportation planning and policymaking, this study will promote continued in-depth investigations by the academic community into the inherent interconnections between the UBE and sustainable travel to achieve urban low-carbon transitions. Future bibliometric studies could build upon these findings by expanding literature sources, comparing results across databases, and utilizing systematic review protocols. Such efforts will further enrich the understanding of how scholarship in this field has progressed and provide guidance on research gaps and future directions.

We hope this review provides a foundation for addressing these gaps, and that future researchers will build upon the state of the field to strengthen the evidence base in understudied domains. Specifically, scholars could consider developing analytical techniques

suited for data-scarce contexts, leveraging multisource heterogeneous data, or conducting comparative studies across different regions to improve generalizability. Pursuing innovative data collection and longitudinal evaluations would also deepen the understanding of UBE planning outcomes. By tackling limitations, researchers can expand the scholarly discourse and inform sustainable transportation policies worldwide.

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