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Global Research Trends in Urban Parking Systems and Traffic Management: A Bibliometric Analysis (2000-2024)

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ABSTRACT: Urban growth has significantly exacerbated parking shortages and traffic control challenges, making them central concerns in urban mobility planning and sustainable city development. Inadequate parking supply, fragmented management strategies, and ineffective traffic control systems have contributed to severe congestion, increased vehicle emissions, inefficient fuel consumption, and reduced urban quality of life. Research across multiple disciplines has expanded rapidly in this area, creating the need for a comprehensive review to map its key themes and future directions. This study examined global research on parking and traffic management from 2000 to 2024, highlighting major research themes, influential publications, and collaboration networks among researchers. A total of 1,847 articles and conference papers from Scopus and Web of Science were analyzed using Bibliometrix in R, VOSviewer, and statistical tools to evaluate publication trends, citation patterns, keyword co-occurrence, collaboration networks, and thematic evolution. Descriptive, network, and temporal analyses were employed to identify both the growth in publication output and the shifting focus within the field. The results showed that research output increased steadily, with a notable surge after 2015, coinciding with the expansion of smart city initiatives, digital transformation, and the implementation of intelligent transportation systems. Several key research themes emerged, including smart parking technologies, traffic flow optimization, sustainable urban mobility solutions, and autonomous vehicle systems. China, the United States, and Germany were identified as the leading contributors to research output, while international collaboration increased significantly, reflecting the global nature of urban transportation challenges. Overall, the findings indicated a clear transition from early studies focused on parking demand and congestion analysis toward technology-driven, data-oriented, and sustainability-focused research approaches. Parking systems and traffic management have therefore become essential components of integrated urban mobility strategies.

KEYWORDS: Parking systems; traffic management; bibliometric analysis; smart cities

1. Introduction

Parking systems and traffic management formed vital components of urban mobility networks, directly influencing congestion levels, environmental conditions, economic productivity, and quality of life for city residents. In rapidly urbanizing cities, insufficient parking provision and ineffective traffic control frequently led to congestion, prolonged travel times, excessive fuel consumption, and increased emissions. These conditions demonstrated that parking and traffic management should be addressed not merely as operational concerns but as integral elements of urban transportation planning shaped by policy frameworks and mobility behavior patterns [1, 2]. Rising numbers of private vehicles driven by urban expansion and economic growth, intensified stress on urban parking infrastructure. Private cars were often preferred over buses for convenience, resulting in rapidly increasing demand in busy downtown areas. Although off-street parking facilities partially alleviated the problem, central districts remained undersupplied, pushing drivers toward on-street spaces [3, 4]. This situation triggered repeated search loops, exacerbating congestion and deepening traffic gridlocks. Consequently, parking policies evolved from secondary traffic tools to frontline instruments in urban transport strategy [5].

Growing mobility demands prompted the adoption of smart city strategies, emphasizing data-driven optimization of urban services through digital technologies, sensors, and ICT networks [6, 7]. Smart parking systems, adaptive traffic signals, and continuous monitoring platforms were increasingly deployed to enhance operational efficiency and enable rapid responses. However, the volume of mobility data challenged conventional cloud infrastructures, creating latency and real-time processing issues [8, 9]. Edge computing emerged as a promising solution for time-critical applications, including parking monitoring and traffic management in smart cities [10]. Inefficient parking and traffic arrangements also imposed significant economic and environmental costs. Vehicles circulating in search of parking contributed substantially to congestion, fuel wastage, and greenhouse gas emissions, while dedicating scarce urban land to parking carried high opportunity costs [4, 11, 12]. These challenges highlighted the need for agile, data-driven solutions capable of streamlining traffic flows while advancing urban sustainability. Advances in vehicular traffic management systems (VTMS) demonstrated the potential of smart technologies in mitigating congestion. Modern VTMS combined computational power with real-time traffic feeds to implement density-based routing strategies that outperformed traditional control methods [13]. Furthermore, connected and automated vehicles, vehicle-to-infrastructure communication, and data analytics enhanced real-time monitoring and predictive traffic management capabilities [14, 15].

Despite these developments, research on parking and traffic management remained dispersed across transport engineering, urban planning, computer science, environmental studies, and policy domains [16, 17]. Most reviews focused narrowly on technical aspects such as parking algorithms or traffic flow adjustments, neglecting broader trends and long-term implications [13, 18]. Additionally, studies were concentrated in developed countries, leaving challenges faced by developing regions underexplored [12, 19]. To address these gaps, a comprehensive understanding of global research trends was needed. Bibliometric tools provided an objective means to map knowledge landscapes, identify influential studies, chart collaboration networks, and trace thematic evolution over time [20]. This study conducted a bibliometric analysis of global research on parking systems and traffic management spanning

2000–2024, highlighting patterns, key contributions, and directions for future research and urban mobility policy development.

2. Materials and Methods

2.1. Research design.

This paper adopted a structured bibliometric approach to analyze the development, growth, and thematic shifts in academic research on parking systems and traffic management. Such an approach proved effective for condensing large volumes of literature to reveal trends in publication output, influential works, and the evolution of research topics over time. Our methods followed established protocols for rigorous bibliometric analysis, emphasizing transparency, reproducibility, and robust analytics [20]. By combining quantitative metrics with network mapping and thematic exploration, this framework provided a comprehensive view of the field’s trajectory and knowledge flows.

2.2. Data sources and database selection.

Bibliographic records were sourced from two leading databases: Scopus and Web of Science Core Collection. Scopus was selected for its broad coverage of peer-reviewed journals and conference papers, along with reliable metadata across disciplines. Web of Science was included for its historical depth and precise citation tracking. Both databases outperformed alternatives such as Google Scholar due to stricter quality control, standardized data formatting, and compatibility with large-scale bibliometric analyses [21]. Using both databases together enhanced data reliability and addressed potential coverage gaps. We excluded Google Scholar and regional databases to avoid inconsistent metadata, duplicate records, and poor compatibility with bibliometric tools. However, this approach may have omitted certain region-specific studies, particularly from emerging economies.

2.3. Search strategy.

A structured search strategy was designed to capture relevant publications on parking systems and traffic management. Queries targeted titles, abstracts, and keywords to ensure both precision and breadth. The analysis focused on peer-reviewed journals, conference papers, and review articles, all in English, spanning 2000–2024 to cover foundational research through recent technological developments. Subject areas included engineering, computer science, environmental studies, and social sciences, reflecting the interdisciplinary nature of the topic. The queries were applied consistently across both databases to ensure comprehensive coverage:

("parking system*" OR "smart parking" OR "parking management")

AND

("traffic management" OR "traffic optimization" OR "urban mobility" OR "intelligent transportation system*")

This query was applied across the Title, Abstract, and Keyword fields in both databases to ensure high precision while capturing all relevant publications.

2.4. Inclusion and exclusion criteria.

Tight inclusion and exclusion criteria ensured that the literature was relevant and of high quality. The inclusion criteria comprised peer-reviewed publications that explicitly focused on parking systems, traffic management, or integrated urban mobility solutions and reported a clear research methodology. Publications written in English and indexed in the selected databases were also included. Conversely, non-academic documents such as books, reports, editorials, and opinion pieces were excluded. Studies focusing solely on vehicle mechanics, road construction, or unrelated engineering topics were also removed. Duplicates and publications lacking full or reliable bibliometric information were excluded during the screening stage.

2.5. Literature selection process using PRISMA framework.

The screening process followed PRISMA guidelines to ensure transparency, reproducibility, and methodological rigor [22]. At the identification stage, 3,247 records were retrieved from Scopus and Web of Science. After removing duplicates, 2,891 publications remained. During the screening stage, titles, abstracts, and keywords were assessed to determine thematic relevance to parking systems and traffic management research.The eligibility assessment further excluded publications unrelated to urban mobility, vehicle mechanics, or infrastructure construction without a traffic or parking focus. Following this process, 1,847 publications met all inclusion criteria and were retained for bibliometric analysis. The PRISMA flow diagram illustrating the selection procedure is presented in Figure 1.

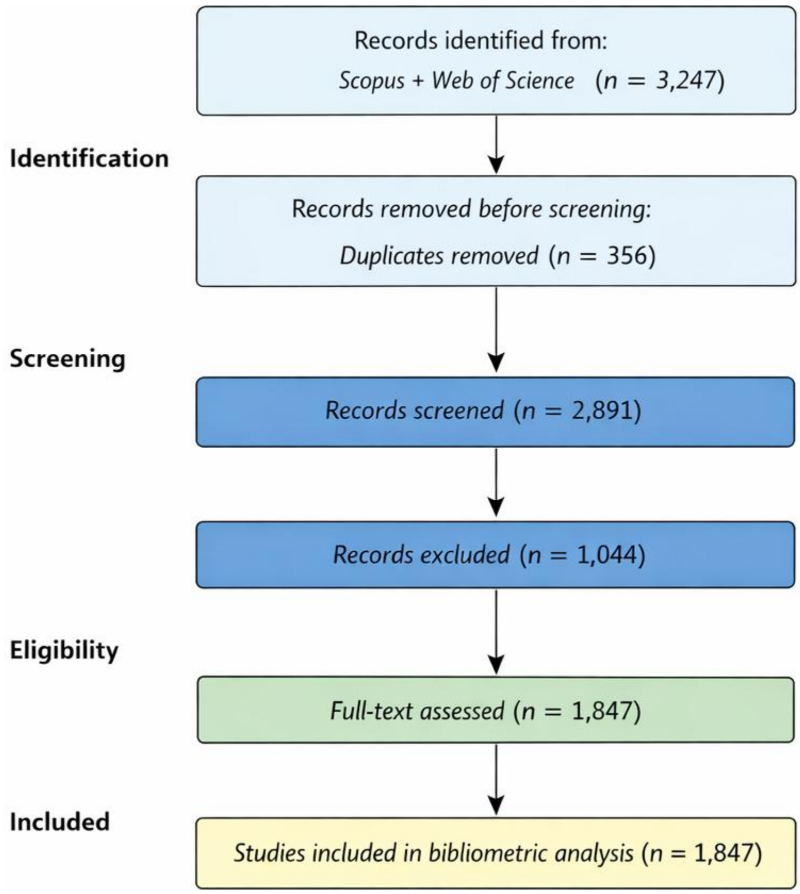


Figure 1. PRISMA flow diagram.

2.6. Data collection and processing.

The database searches initially retrieved 3,247 records. After removing duplicates, 2,891 unique publications remained. Screening of titles, abstracts, and keywords for topical relevance resulted in 1,847 works being selected for full bibliometric analysis. Bibliometric information including authors, institutions, publication years, journals, citations, keywords, and abstracts, was extracted. Name variants, affiliation inconsistencies, and term mismatches were standardized to ensure data integrity and smooth analysis.

2.7. Bibliometric thresholds and normalization.

For keyword network analysis, terms were required to appear at least five times, while citation burst detection focused on publications with ten or more citations to minimize noise. VOSviewer normalized networks using association strength to ensure fair comparisons of node importance. Collaboration maps employed fractional counting to avoid bias from multi-author publications. These thresholds provided a balance between detecting significant patterns and maintaining robust analysis, in line with established bibliometric protocols [23].

2.8. Data analysis techniques.

Multiple analytical approaches were employed to examine different dimensions of the research landscape. Descriptive statistics captured publication trends, citation trajectories, and global output distribution. Citation analyses identified the most influential papers, authors, and journals, while co-authorship networks revealed collaborative patterns among researchers, institutions, and countries. Keyword clustering and thematic mapping traced major topics and their temporal evolution. Bibliometrix in R was used for core metric calculations and statistical analysis [20]. VOSviewer visualized collaboration networks and thematic groupings, while Gephi was applied to more complex network representations. Time-series and geographic analyses highlighted emerging trends and global research patterns, providing a comprehensive overview of the evolution of parking systems and traffic management research and informing directions for future study.

3. Results and Discussion

3.1. Citation analysis.

Citation metrics were interpreted with caution due to inherent limitations. Self-citations, discipline-specific citation behaviors, and the age of publications all affected raw citation counts. Newer papers naturally accumulated fewer citations because of time lags, while methodology-focused studies often attracted citations from related fields beyond parking and traffic management. Additionally, high citation counts reflected academic attention rather than direct real-world impact or policy influence.

3.2. Most influential publications based on citation analysis.

The citation review identified the most influential works in parking systems and traffic management research. Table 1 presents the ten most cited publications. As shown in Table 1, citation counts ranged from approximately 750 to over 18,000, illustrating considerable variation in academic influence across different studies. The leading publication applied

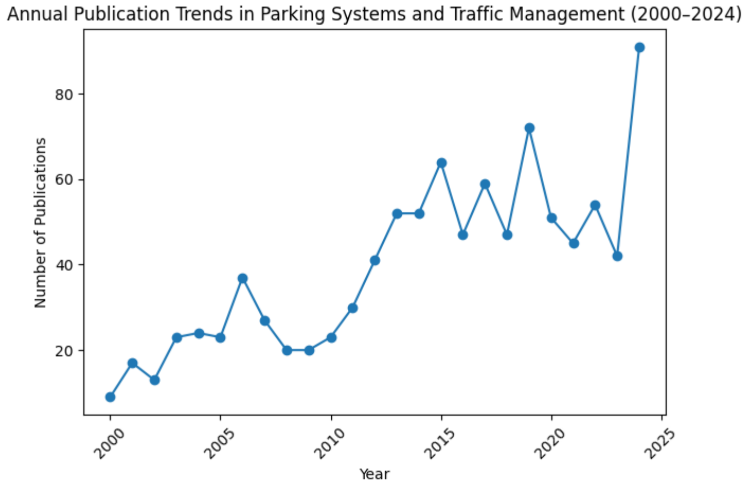
YOLOv4 for deep learning-based object detection, which has become widely adopted in smart transportation technologies, including traffic surveillance, vehicle tracking, and intelligent parking systems. Its prominence demonstrates the growing integration of computer vision and artificial intelligence in contemporary parking and traffic management research, particularly for real-time monitoring, automated operations, and data-driven decision-making [12]. Key cited publications also examined autonomous vehicles and their broader impacts on transportation networks. They highlighted how self-driving technologies and ride-sharing models reshaped travel patterns, reduced parking demand, and improved urban traffic flow, further integrating vehicle innovations with parking systems research [13]. Overall, the most-cited studies stood out by introducing novel methodologies or technological advancements rather than focusing on incremental policy adjustments or narrow case studies.

Table 1. Most influential publications based on citation counts.

No	Authors	Source	Document	Citation	Year
1	D.C. Shoup [3]	Transport Policy	Cruising for Parking	~1,300	2006
2	R.C. Hampshire, D.C. Shoup [4]	Journal of Transport Economics and Policy	What Share of Traffic is Cruising for Parking?	~900	2018
3	R. Arnott, E. Inci [11]	Journal of Urban Economics	An Integrated Model of Downtown Parking and Traffic Congestion	~900	2006
4	A. Bochkovskiy, C.Y. Wang, H.Y.M. Liao [12]	arXiv / Computer Vision	YOLOv4: Optimal Speed and Accuracy of Object Detection	18,800+	2020
5	D.J. Fagnant, K. Kockelman [13]	Transportation Research Part A	Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations	~3,000	2015
6	D.J. Fagnant, K.M. Kockelman [14]	Transportation Research Part C	The Travel and Environmental Implications of Shared Autonomous Vehicles	~1,600	2014
7	S.A. Shaheen, A.P. Cohen [15]	Transportation Research Part A	Shared Mobility Policies for Reducing Congestion and Parking Demand	~850	2016
8	M. Millard-Ball [16]	Transport Policy	The Limits to Planning for Parking	~750	2010
9	J.P. Hubaux, S. Capkun, J. Luo [17]	IEEE Security & Privacy	The Security and Privacy of Smart Vehicles	~1,000	2004
10	F. Wortmann, K. Flüchter [18]	Business & Information Systems Engineering	Internet of Things: Technology and Value Added	~1,300	2015

3.3. Publication trends and growth patterns.

Figure 2 illustrates the annual publication distribution from 2000 to 2024, while Table 2 summarizes yearly output and citation metrics. Citation counts per article were normalized using age-adjusted scoring combined with a three-year rolling median to mitigate time-related biases and smooth outliers, particularly for recent publications affected by citation delays. The data revealed a steady increase in research output over time. Between 2000 and 2008, publication numbers remained relatively low but consistent, reflecting early investigations into parking demand, congestion, and pricing strategies—primarily approached through analytical and policy frameworks. Publication growth accelerated between 2009 and 2016, reflecting the rise of intelligent transportation systems and early smart parking solutions. A pronounced surge occurred post-2017, coinciding with the global rollout of smart city initiatives, IoT-enabled monitoring, and data-driven traffic management technologies. This evolution indicates a fundamental shift in the field: research on parking systems transitioned from isolated studies toward integrated frameworks within broader urban mobility and smart infrastructure strategies.



Figures 2. Annual publication trends in parking systems and traffic management (2000–2024).

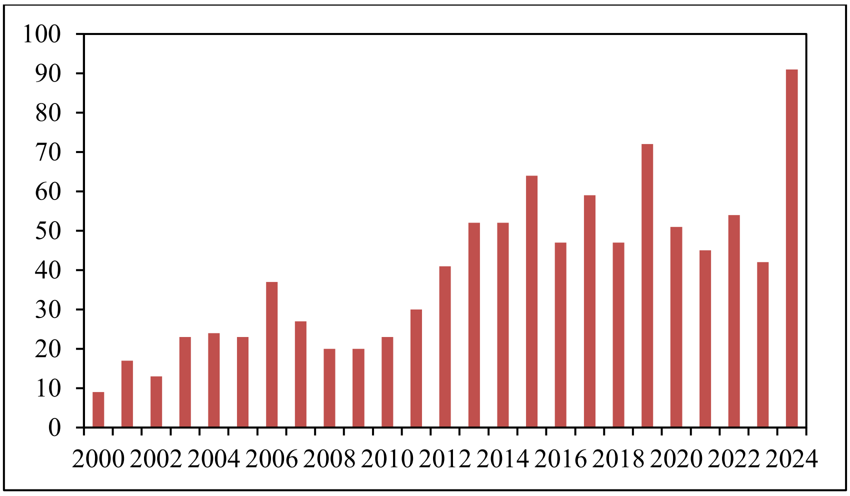
Table 2. Research development and citation metrics from 2000–2024.

No	Year	Publications	Citation per Article (Adjusted)
1	2000	9	257
2	2001	17	352.47
3	2002	13	247.31
4	2003	23	343.3
5	2004	24	377.54
6	2005	23	262.21
7	2006	37	302.11
8	2007	27	290.33
9	2008	20	240.95
10	2009	20	195.65
11	2010	23	256.83
12	2011	30	244.03
13	2012	41	182.17
14	2013	52	192.31
15	2014	52	228.19
16	2015	64	253.59
17	2016	47	188.85
18	2017	59	159.1
19	2018	47	121.66
20	2019	72	69.33
21	2020	51	107.73
22	2021	45	95.12
23	2022	54	38.45
24	2023	42	18.27
25	2024	91	6.84

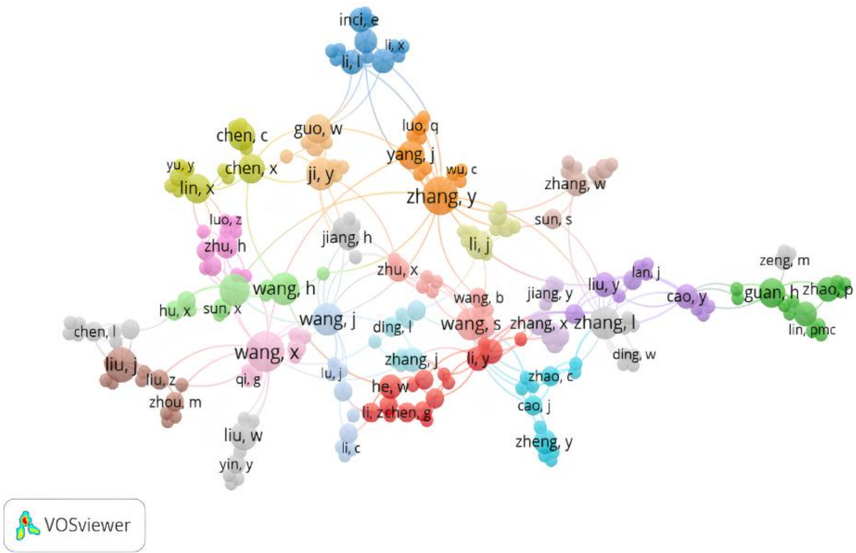
3.4. Research development, keyword dynamics, and author collaboration.

Table 2 presents yearly publication totals and average citations per paper, while Figure 3 illustrates the overall growth trend. Citation rates declined in recent years due to the natural lag effect, as newly published papers had not yet accumulated citations. Nevertheless, publication volume continued to rise, particularly after 2015, reflecting sustained scholarly interest and an expanding research field. These trends indicate that research focus gradually shifted from conventional analyses of parking supply and demand toward technology-driven, system-level approaches in parking and traffic management. Keyword analysis further highlighted this evolution, showing increasing attention to topics such as smart parking technologies, intelligent transportation systems, IoT integration, and data-driven traffic optimization. The dynamics of keyword co-occurrence reveal thematic clusters that track the transition from foundational operational studies to advanced, technology-oriented frameworks.

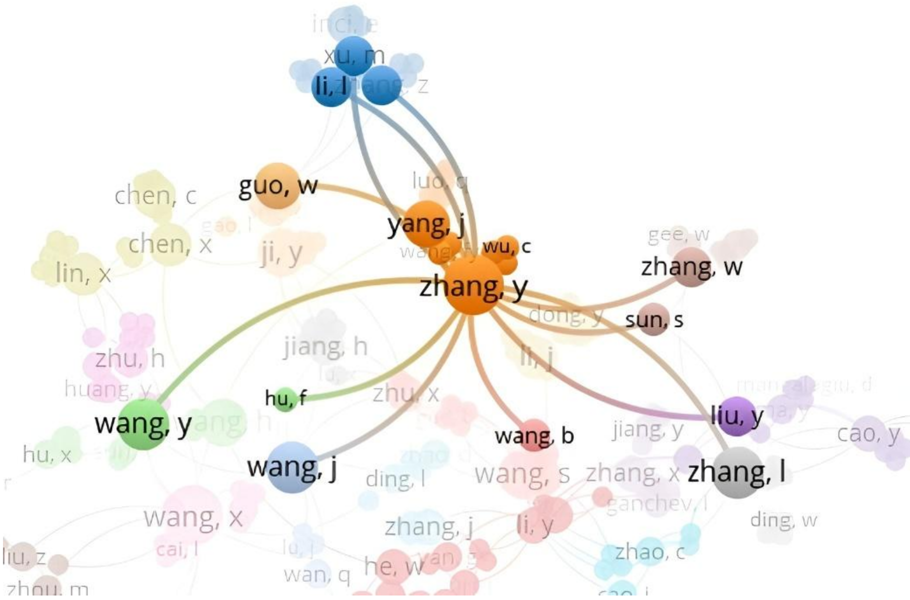
The structure of research collaboration was visualized through the author co-authorship network (Figure 4). The network revealed several prominent clusters anchored around high-output authors such as Wang X, Zhang Y, and Liu J, who served as central nodes linking multiple collaborators. This pattern reflects the technology-intensive nature of parking and traffic research, where dedicated teams develop sensing systems, optimization algorithms, and data pipelines. Figures 5–7 provide detailed views of these lead author networks, showing that prolific researchers generally operated within stable teams. While this arrangement fostered depth and expertise, it suggested relatively weak inter-cluster collaboration. Network metrics confirmed these observations: the modularity score was 0.71, indicating well-defined collaboration clusters, while the overall network density of 0.024 reflected a sparse global collaboration structure. Degree centrality analysis identified several authors as key knowledge hubs, facilitating interdisciplinary connections and promoting the flow of insights across research clusters [24−26].



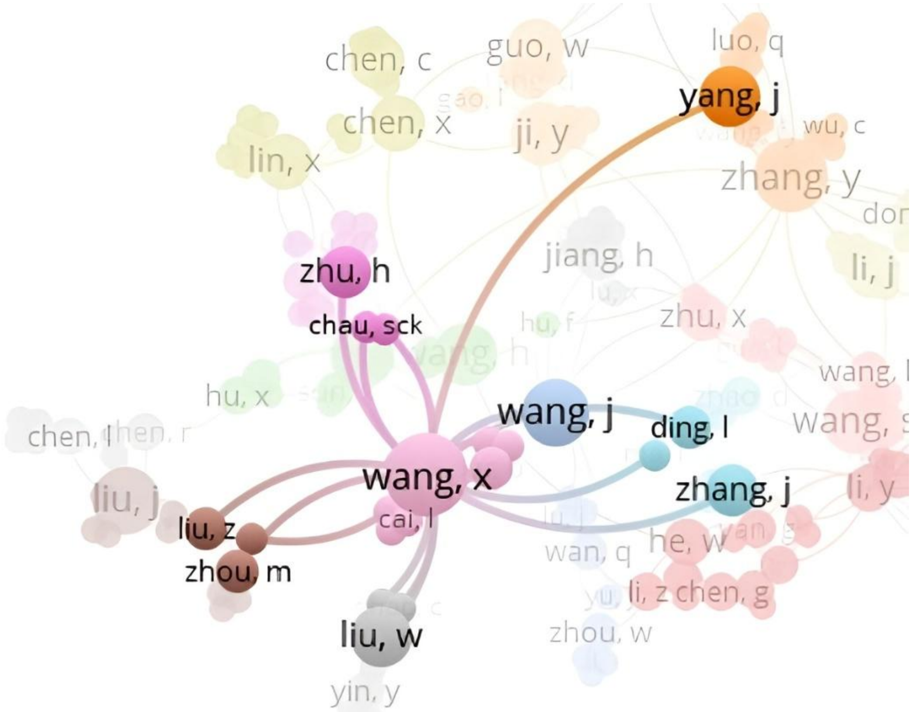
Figures 3. Research development trends based on annual publication output.



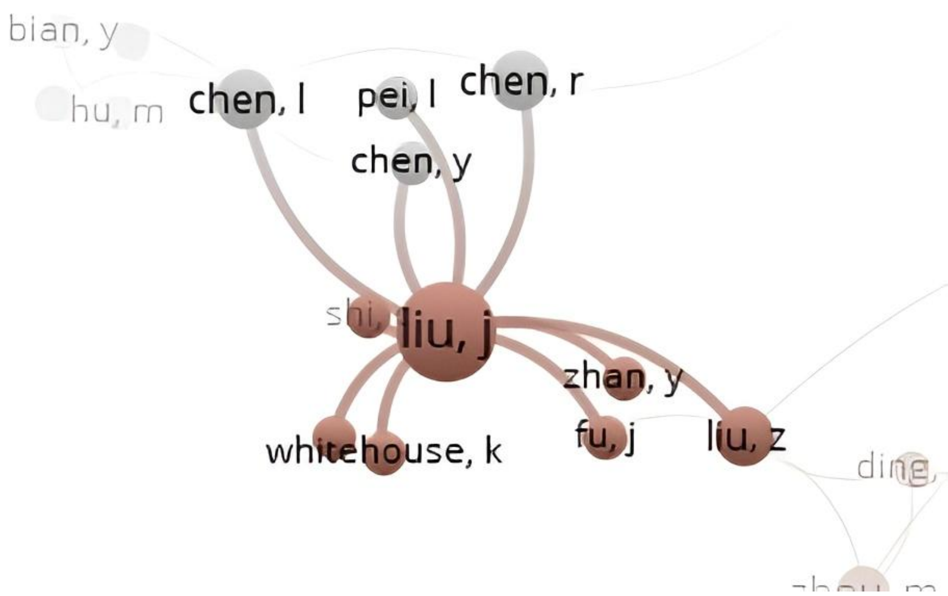
Figures 4. Author collaboration network in parking systems and traffic management research.



Figures 5. Author collaboration network of Zhang, Y.



Figures 6. Author collaboration network of Wang, X.



Figures 7. Author collaboration network of Liu, J.

3.6. Most productive authors.

Author productivity and collaboration patterns are summarized in Table 3, which lists the most prolific researchers in parking systems and traffic management, along with their total link strength in co-authorship networks. Wang X ranked highest in publication count, followed closely by Zhang Y and Liu J. The elevated total link strength for these authors indicates not only a high volume of output but also extensive collaborative engagement, highlighting their central roles in advancing research on smart parking systems, traffic optimization, and related technologies. Table 3 shows that several other authors, including Zhang L, Ji Y, and Wang S, also contributed significantly to the field. Their high link strength demonstrates active participation in research networks, fostering knowledge exchange and joint development of methodologies and technological solutions. The combination of prolific output and strong collaboration suggests that these researchers serve as key knowledge hubs, driving innovation and shaping research agendas in both applied and theoretical aspects of urban mobility management. The collaboration metrics further reveal that productivity in this domain is closely linked to teamwork, where tightly connected clusters enable rapid dissemination of new ideas, methods, and tools. Notably, Wang X, Zhang Y, and Liu J appear as anchors in overlapping clusters, bridging different research teams and facilitating interdisciplinary linkages between transportation engineering, computer science, and urban planning.

Table 3. Most productive authors and collaboration strength.

No	Author	Documents	Total Link Strength
1	Wang, X	8	21
2	Zhang, Y	7	18
3	Liu, J	6	10
4	Zhang, L	5	18
5	Ji, Y	5	16
6	Wang, S	5	16
7	Wang, J	5	15
8	Wang, Y	5	13
9	Buehler, R	5	11
10	Wang, H	5	6

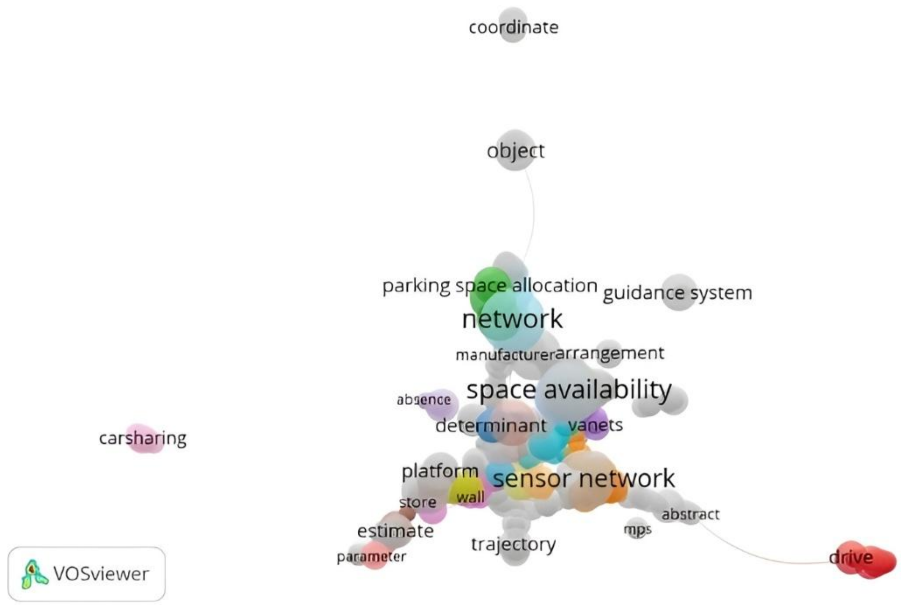
3.7. Keyword co-occurrence and thematic structure.

Table 4 first outlines the disciplinary distribution of publications, providing context for the research landscape before delving into keyword networks. To understand the research landscape of parking systems and traffic management, it was essential first to examine the disciplinary distribution of publications. This step provides insight into which academic fields have driven research efforts, how knowledge has been generated, and where interdisciplinary connections emerge. Identifying the subject areas not only frames the context for subsequent keyword and thematic analyses but also highlights the domains that have contributed most to advancing parking and traffic management solutions. The analysis revealed that engineering and computer science dominate the field, reflecting the technical and methodological focus of studies on traffic control, sensor-based monitoring, and optimization algorithms. Transportation research offered applied insights into mobility patterns, operational efficiency, and system-level evaluations. Environmental science contributions highlighted sustainability and emission reduction concerns associated with urban transport, while urban studies and social sciences brought attention to policy, behavioral, and societal dimensions of mobility planning. Decision sciences captured modeling, forecasting, and strategic planning perspectives. This multidisciplinary spread underscores the complex and interwoven nature of parking and traffic management research, where technology, operational systems, environmental considerations, and human behavior intersect. It establishes a foundation for exploring intellectual structures through keyword co-occurrence, co-authorship networks, and thematic clustering, helping to reveal emerging trends and key knowledge hubs in the field.

Table 4. Subject area distribution in parking systems and traffic management research.

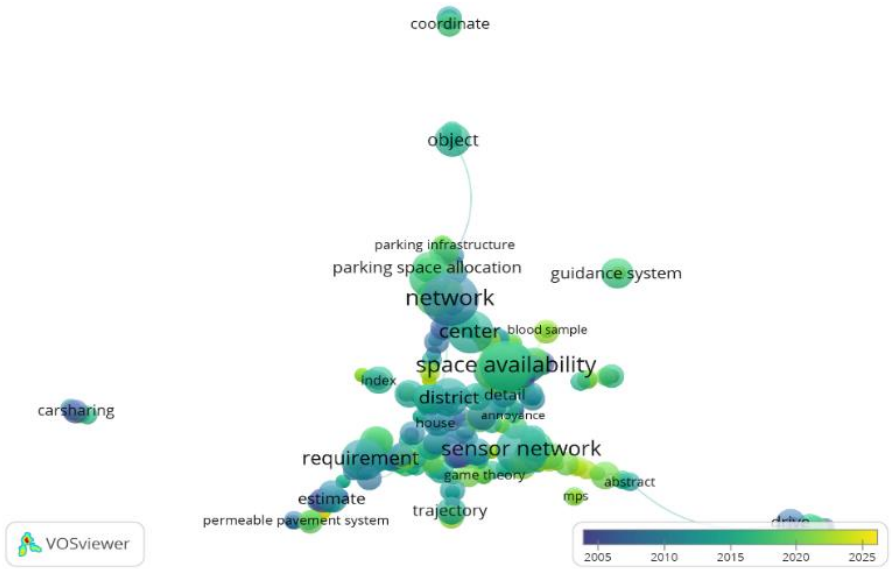
No	Subject Area	Number of Documents	Percentage (%)
1	Engineering	412	34.5
2	Computer Science	365	30.6
3	Transportation	210	17.6
4	Environmental Science	98	8.2
5	Urban Studies	54	4.5
6	Decision Sciences	32	2.7
7	Social Sciences	23	1.9

Engineering and computer science dominate the field, reflecting the strong technical foundation of parking and traffic management research. Transportation and environmental science publications provide context and applied relevance, while urban studies, decision sciences, and social sciences capture policy, planning, and behavioral dimensions. This multidisciplinary distribution highlights the field’s complexity, spanning applied technology, systems optimization, and societal impact considerations. The keyword co-occurrence network (Figure 8) mapped links among the most frequently used author keywords, revealing the field’s core intellectual structure. Central nodes such as “parking system,” “sensor networks,” and “space availability” indicate that research heavily emphasizes technological monitoring, sensing mechanisms, and real-time information processing. These keywords occupy dense clusters, signaling their foundational role in shaping contemporary studies on automated parking, traffic surveillance, and data-driven urban mobility solutions.



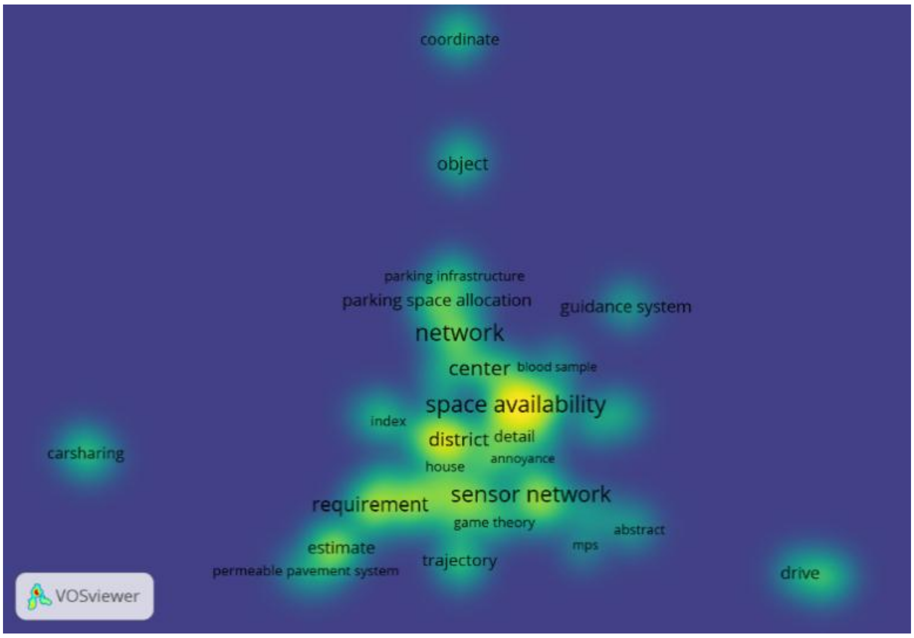
Figures 8. Keyword co-occurrence network visualization.

Temporal overlay visualization (Figure 9) highlights the evolution of thematic focus over time. Early research (2000–2010) concentrated on conventional parking supply–demand analysis, accessibility, and traffic control strategies. In contrast, recent studies increasingly focus on smart parking systems, IoT-enabled infrastructures, artificial intelligence, and real-time decision-making. This shift reflects broader trends toward smart mobility networks and digitally integrated urban transport systems, where technological adoption drives operational efficiency and user-centric solutions.



Figures 9. Overlay visualization of keyword evolution over time.

Cluster analysis of keywords (Figure 10) further clarifies the structure of research themes. Table 5 summarizes the major clusters, identifying the central research streams, representative keywords, leading authors, and thematic emphasis. Four prominent clusters emerge: smart parking, traffic optimization, sustainable mobility, and autonomous vehicles.



Figures 10. Clustered keyword network in parking systems and traffic management research.

Table 5. Summary of major research clusters.

Cluster	Research Theme	Representative Keywords	Leading Authors	Research Focus
1	Smart Parking	IoT, sensors, real-time parking	Zhang Y, Wang X	automated parking detection
2	Traffic Optimization	congestion control, routing	Liu J	traffic efficiency
3	Sustainable Mobility	emission reduction	Buehler R	sustainable transport
4	Autonomous Vehicles	AV, connected vehicle	Fagnant D	mobility automation

3.8. Journal distribution.

Table 6 presents the leading peer-reviewed journals that have driven research on parking systems and traffic management. These journals, all internationally recognized and indexed in Scopus and Web of Science, have shaped both the technical and applied dimensions of the field. Technology-focused outlets such as *IEEE Access*, *Sensors*, and *Applied Sciences* emphasized intelligent transport systems, sensor networks, and artificial intelligence applications, reflecting the increasing reliance on digital tools and data-driven solutions in urban mobility. In contrast, transportation and policy-oriented journals, including *Transportation Research Part A: Policy and Practice*, *Transportation Research Part C: Emerging Technologies*, and *Transport Policy*, concentrated on mobility strategies, traffic optimization, and sustainable urban transport governance. The combined influence of these journals highlights the interdisciplinary nature of the research, where engineering innovations, smart city infrastructures, and policy-driven approaches converge to advance parking and traffic management solutions worldwide.

Table 6. Leading journals publishing research on parking systems and traffic management.

No	Journal Source	Publications	Total Citations
1	IEEE Access	64	3,842
2	Sustainability	58	2,915
3	Sensors	47	2,104
4	Transportation Research Part A: Policy and Practice	39	4,226
5	Transportation Research Part C: Emerging Technologies	35	5,118
6	Applied Sciences	31	1,276
7	Future Generation Computer Systems	26	2,487
8	Journal of Advanced Transportation	24	1,032
9	Transport Policy	21	1,964
10	Sustainable Cities and Society	19	2,356

3.9. Research evolution and theoretical interpretation.

Bibliometric analysis revealed a clear evolution in parking systems and traffic management research. Early studies primarily focused on conventional parking demand, accessibility, and traffic control approaches. Over time, research shifted toward technology-driven, system-level urban mobility studies. The smart parking cluster aligned with smart city and IoT implementations, leveraging edge computing, sensor networks, and real-time decision-making to enhance infrastructure flexibility and operational efficiency [8, 10, 15]. Traffic optimization research combined algorithmic and computational methods to tackle congestion and routing challenges, integrating data-rich mobility models and intelligent transport system approaches [6, 7, 11]. Sustainable mobility work increasingly emphasized environmental and social objectives, echoing frameworks advocating policy measures that balance parking supply, traffic flow, and emission reduction [3, 5]. The autonomous vehicle cluster highlighted socio-technical transitions, illustrating how self-driving technology, vehicle-to-everything (V2X) connectivity, and ride-sharing reshaped travel patterns and parking demand [13, 14].

Network analysis reinforced these trends. Modularity at 0.71 and a network density of 0.024 indicated strong, well-defined author clusters with limited cross-group collaboration. Degree centrality highlighted key authors as knowledge hubs, showing that specialized teams drove technological advances while broader integration across research groups remained limited. Compared with prior bibliometric studies, these findings demonstrated stronger convergence between artificial intelligence adoption, sustainability-oriented mobility planning, and governance-focused frameworks [13, 16, 27]. Thematically, clusters reflected alignment with established urban mobility and smart city paradigms: smart parking captured the push toward data-driven infrastructure, sustainable mobility aligned with core transport planning frameworks, and autonomous vehicle research supported socio-technical transition theory, showing evolution via interactions between technology, policy, and user behavior [14, 17, 19].

3.10. Practical implications, research gaps, and future directions.

Findings suggested that effective parking and traffic management increasingly depended on integrated, technology-supported approaches rather than isolated regulatory measures. Policymakers, particularly in developing contexts, should prioritize IoT-enabled smart parking systems to optimize space usage and reduce congestion from vehicles searching for parking [8, 15]. Data-driven traffic management strategies, including adaptive routing and real-time monitoring, could mitigate travel delays and lower vehicle emissions [6, 7]. Integrating parking and traffic strategies into broader sustainable mobility frameworks was critical to achieving environmental and social objectives [3, 5, 19]. Enhancing global knowledge sharing and collaboration was essential, especially for cities with limited infrastructure and policy development [12, 25]. Research combining bibliometric insights with empirical case studies in underrepresented regions was recommended to deliver practical, context-sensitive solutions [9, 27].

Despite notable progress, clear research gaps persisted. Social equity, user behavior, and accessibility issues remained underexplored, despite their centrality to inclusive urban mobility. Climate-adaptive and environmentally resilient parking infrastructure was also underexamined, offering opportunities for cross-disciplinary studies [24]. Data-intensive, technology-first approaches dominated traffic management research, but integration of social, behavioral, and governance dimensions remained limited [26]. Future research should prioritize hybrid approaches that combine empirical evidence, social considerations, and technology-driven models to deliver holistic, locally applicable solutions.

4. Conclusions

This bibliometric review charts parking systems and traffic management studies from 2000-2024, tracking structural changes, key themes, and hot paths in this fast-paced field. Publication counts have shot up steadily, cementing parking and traffic fixes as core pieces in urban mobility plans, green efforts, and smart city rollouts. Results show a big swing: away from basic parking demand, congestion woes, and policy gaps toward tech-heavy tactics mixing IoT, AI, big data crunching, and autonomous rides. Top papers bunch around fresh tech breakthroughs, locking in innovation as the driving force behind current research trails. Sustainability and policy themes are gaining ground too, signaling that tech fixes need tight links to governance setups and lasting city goals. Collaboration maps show work bunched in a few tight author groups great for deep dives within niches, but cross-team and cross-field ties stay thin, opening doors for wider teamwork across areas andplaces. Global reach grows, yet developing-region hurdles get short shrift. Theme tracking confirms parking/traffic studies now span linked fronts: smart parking tech, flow optimization, green urban travel, and self-driving/connected vehicles. Urban mobility challenges span many angles, demanding solutions that blend tech, social needs, environmental aims, and policy tools.This study has limits like sticking to English papers and citation delays hitting new work, but its bibliometric setup gives solid ground for tracking long-term trends and priority gaps.Overall, it maps the field's core structure, flags key shifts and holes, and pushes for cross-field teamwork, local-fit fixes, and tighter tech-policy links to build leaner, greener, fairer city travel ahead.

Author Contribution

Yusra Aulia Sari led study conceptualization, shaped the research framework, and oversaw the full bibliometric analysis. Muhammad Hauzan Suhenal handled data gathering, screening, processing, and core analysis through bibliometric tools. Andri Irfan Rifai drove results interpretation, visualizations, and drafting of the Results and Discussion sections.All authors participated in manuscript writing, critical revision for intellectual content, and approved the final version of the manuscript.

Competing Interest

The authors declare that they have no competing interests, financial or non-financial, that could be perceived as influencing the work reported in this manuscript. The research was conducted independently, and no external organization influenced the study design, data analysis, interpretation of results, or the preparation of the manuscript.

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