A Review of Three–Dimensional Research on Urban Recreation Space Based on CiteSpace

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Abstract In this study, CiteSpace software is used to carry out visual analysis on the three-dimensional research literature on urban recreation space from the perspective of compact city theory in the past 20 years, exploring the scientific development trend and research hotspots in this field. The results show that the number of published documents shows a fluctuating upward trend, and the significant growth rate reflects the role of policy orientation in promoting the concept of compact city. The co-occurrence analysis of keywords reveals the research hotspots of "compact city", "recreation space" and "urban park", while the emergence of new keywords such as "vertical city" and "spatial justice" indicates the new trend of recent research. The cluster analysis and timeline map further show the evolution of research themes, with "compact city" being the largest cluster and having rich connections with other themes such as "urban design" and "urban park".

The concept of compact cities aims to reduce the impact of cities on the environment while achieving efficiency, orderliness, and livability by increasing urban density, optimizing land use, and promoting functional mix. In 2015, the Central Urban Work Conference of China proposed the concept of "intensive development, smart growth, and compact cities", aiming to guide cities to achieve more sustainable and efficient development. Urban recreational space is an important component of the urban ecosystem, and the design and management of urban recreational space are of great significance for achieving the sustainable development goals of compact cities.

Under the concept of compact cities, three-dimensional recreational space effectively expands the capacity of urban recreational spaces through vertical or multi-level design, and also adds new visual and spatial dimensions to the urban landscape, providing different perspectives for the diversity of city space. Firstly, three-dimensional recreational space can efficiently utilize limited urban land resources, increase the supply of recreational space through vertical expansion, and alleviate the problem of insufficient recreational spaces in urban central areas. Secondly, three-dimensional design can create diverse recreational environments that meet the needs of different ages, interests, and activities, enhancing the inclusiveness and attractiveness of urban recreation space. In addition, three-dimensional recreation space can promote the diversity of urban ecology, increase urban green area and improve urban microclimate through designs such as green roofs and vertical gardens. However, the three-dimensional development of urban recreation space also faces a series of challenges. At the technical level, the design and construction of three-dimensional recreation space need to consider multiple factors such as structural safety, spatial accessibility, and environmental adaptability. At the economic level, the construction and maintenance costs of three-dimensional recreation space are usually higher than those of traditional flat space, requiring reasonable capital investment and operational models. At the social level, the acceptance and use effectiveness of three-dimensional recreation space still need to be verified through empirical research, and residents' recreational behavior and preferences may also change as a result[1-6].

The existing research results have made extensive exploration to urban recreation space under the concept of compact cities. Through the analysis of literature knowledge graphs, it is possible to reveal the research hotspots, cutting-edge trends, and potential research gaps in this field, summarize the research progress of three-dimensional urban recreation space under the theory of compact cities, and thus provide research perspectives and theoretical references for designers.

1 Analysis tools and data sources

Developed by professor Chen Chaomei from Drexel University, USA, CiteSpace is a bibliometric and knowledge visualization software developed based on Java. The core function of this software is to reveal the research frontiers, trends, and evolutionary paths in the discipline field through citation analysis of scientific literature. CiteSpace is capable of processing and analyzing large-scale literature datasets, generating various visual charts including keyword co-occurrence maps, timeline maps, and co-citation clustering maps, thereby providing researchers with an intuitive and interactive research tool[7].

The data source for the study is China National Knowledge Infrastructure (CNKI), which is the largest comprehensive academic literature service platform in China. It includes a large number of literature on urban planning, urban design, urban recreation space, and other fields. The search term combination includes "compact city", "urban recreation space", and "three-dimensional city", aiming to comprehensively cover research literature related to the three-dimensional urban recreation space. The time span is set from 2004 to 2024 to reflect the development trend of this research field in the past twenty years.

2 Trend analysis on number of published documents

According to the filtering and retrieval results of the data sources mentioned above, the overall number of published documents in this field shows a fluctuating upward trend in the time series. The proposal and promotion of the concept of compact cities have a significant impact on the three-dimensional research of

urban recreation space. From the time series changes in the number of published documents, the rapid growth from 2015 to 2018 coincides with the introduction and implementation of the concept of compact cities in China. This indicates that the implementation of the compact city concept has not only promoted research in the field of urban planning and design, but also stimulated attention and exploration of the issue of three-dimensional urban recreation space. Subsequently, the increase of the number of published documents tends to stabilize, reflecting that the field has entered a mature and steadily developing stage (Fig.1).

3 Keyword co–occurrence and hotspots analysis
3.1 High frequency keyword extraction and knowledge graph construction

CiteSpace is used to analyze the keywords of 656 retrieved literature, extracting 235 high-frequency keywords, based on which the knowledge graph is constructed. The knowledge graph visualizes the co-occurrence relationships between keywords, where the size of nodes represents the frequency of keyword occurrence, and the connections between nodes represent their co-occurrence strength. After setting appropriate thresholds, 516 statistically significant connections are filtered out, forming an intuitive co-occurrence network graph (Fig.2).

3.2 Keyword centrality analysis

The betweenness centrality of a keyword is an indicator of its role as a communication bridge in a knowledge network. In this study, the focus is on the betweenness centrality indicator, as it reveals the connectivity and influence of the keyword in the research field. For example, the betweenness centrality value of 0.47 for "compact city" indicates that it plays a core role in the three-dimensional research of urban recreation space and has extensive connections with other keywords. Keywords with high betweenness centrality are often indicators of research hotspots in the field and are also a focus of academic attention (Table 1).

3.3 Timeline and trends of hot key–words

Timeline map is a visualization tool that clusters literature keywords and displays them along a two-dimensional timeline, providing researchers with an effective method for exploring the evolution process and cutting-edge trends of theme clustering. In the study, the timeline map generated by CiteSpace is used to identify the main clusters in the three-dimensional research of urban recreation space, and analyze the development trend of these clusters over time. In the graph, each cluster is composed of a set of keywords that have a high co-occurrence frequency within a specific time period, indicating their close correlation in the research during that period.

The timeline function of CiteSpace is used to carry out further analysis on the evolution trend of hot keywords over time. The timeline map clusters keywords and displays them along the timeline, revealing the shift of research focus during different time periods. The results show that keywords such as "compact city," "recreation space," and "urban park" have been the research hotspots since 2004. In recent years, new keywords such as "vertical cities" and "spatial justice" have emerged, reflecting a shift in research trends towards three-dimensional design, social justice, and environmental sustainability.

In addition, the analysis on burst terms has identified the burst terms in the research field over the past 20 years, and the frequency of their occurrence has significantly increased in a short period of time, indicating the formation of new research hotspots. For example, as the burst terms, "three-dimensional" and "optimization strategy" indicate a sharp increase in the attention to these themes in recent research (Fig.3).

4 Cluster analysis and cutting–edge trends
4.1 Main clustering and keyword analysis

When conducting cluster analysis, focus has been laid on the following main clusters and their characteristics:

(1) Compact city cluster: This cluster is centered around "compact cities", including keywords such as functional mix, city space, and near ground space of high-rise buildings. Compact city cluster reflects the pursuit of high-density, multifunctional, and sustainable development in urban planning, as well as the focus on improving the efficiency of urban spatial utilization.

(2) Recreation space cluster: This cluster focuses on "recreation space" and covers keywords such as urban recreation, recreation behavior, and urban waterfront space. It reveals the increasing demand for urban recreation space and explores the relationship between recreation behavior and urban public space design.

(3) Urban design cluster: This cluster is centered on "urban design", including keywords such as three-dimensional, recreation space, fractal. This cluster reflects the interest in three-dimensional and multi-level spatial design in the field of urban design, as well as in-depth research on urban form and structure.
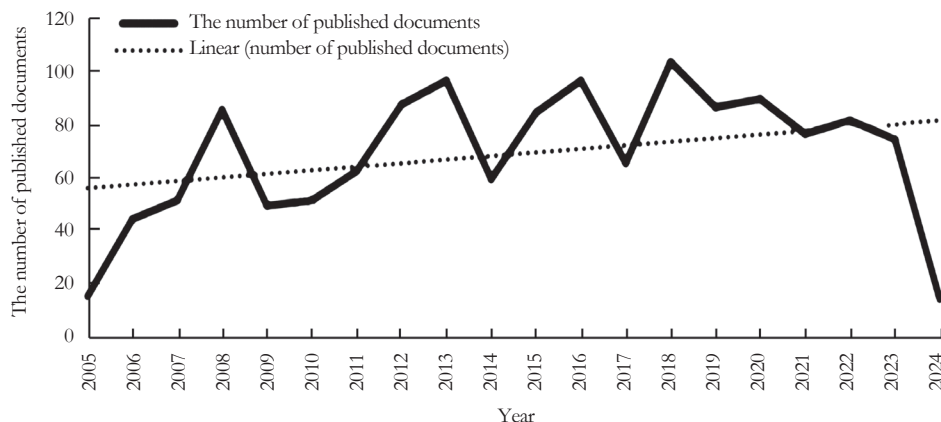

Fig.1   Trend of the number of published documents from 2005 to 2024

Table 1   Keywords of top 10 centrality (Sorted according to the betweenness entrality)

Rank	Keywords	Frequency	Betweenness centrality
1	Compact city	121	0.47
2	Recreation space	78	0.34
3	Urban design	15	0.08
4	Urban park	16	0.08
5	Planning	8	0.04
6	Humanization	2	0.04
7	Small and medium-sized cities	4	0.03
8	Three-dimensional	8	0.03
9	Optimization strategy	3	0.03
10	City	7	0.02

The analysis on these clusters makes it possible to identify the co-occurrence of multiple themes in the three-dimensional research of urban recreation space, as well as the interrelationships and influences between different research themes. The combination of compact cities and recreation space, as well as the integration of urban design and three-dimensional trends, demonstrates the multidimensional thinking in the field of urban planning and design in response to urbanization challenges (Table 2).

4.2 Relationship between clusters and cutting–edge trends

The rich connections between clusters indicate the intersection and fusion between different themes. In particular, the connection between compact cities and clusters such as recreation spaces and urban design reveals that researchers are exploring how to achieve the concept of compact cities through three-dimensional design, and also paying attention to the quality and functionality of recreation space. In addition, the emergence of emerging keywords such as "vertical cities" and "spatial justice" indicates the new directions that future research may focus on, including exploring the vertical development model of cities and considering the justice of city space (Fig.4).

4.3 Multiple theme co–occurrence and cross fusion of research fields

In cluster analysis, the phenomenon of multiple theme co-occurrence indicates that the research field of three-dimensional urban recreation space is experiencing a trend of cross fusion. Such cross fusion is not only reflected in the mutual infiltration between different disciplines, but also in the close integration of theory and practice, which is specifically reflected in the following themes:

(1) The combination of compact cities and recreation space: The rich connections between compact city cluster and recreation space cluster indicate that researchers are committed to exploring how to create high-quality recreation space in compact urban environments. This combination takes into account various factors such as urban density, mixed functions, and residents' quality of life, aiming to achieve sustainable development of the city and maximize residents' well-being.

(2) The integration of urban design and three-dimensional: The appearance of keywords related to three-dimensional, such as "vertical city" and "vertical stacking", demonstrates the attention of the design field to spatial utilization efficiency and urban form innovation. This trend of integration reflects the exploration of three-dimensional space development and multifunctional integration in urban planning and design to adapt to the process of urbanization.

(3) The introduction of social justice and spatial justice: The emerging keyword "spatial justice" appears in multiple clusters, indicating that researchers are beginning to pay attention to the justice of urban recreation space allocation and social inclusiveness. The concept of spatial justice provides a new perspective for the design and management of urban recreation space, emphasizing the importance of ensuring equal recreational opportunities for all residents in the development of compact cities.

(4) Technology application and innovation: The emergence of keywords such as "artificial intelligence" implies the impact of technological progress on the three-dimensional research of urban recreation space. The application of technology provides new tools for solving urban
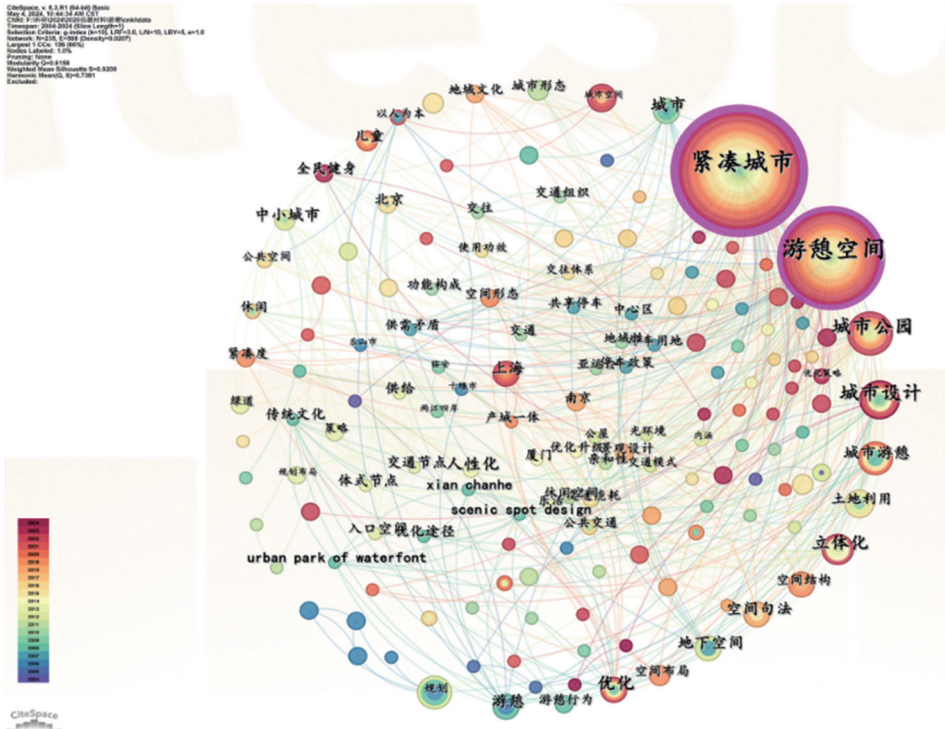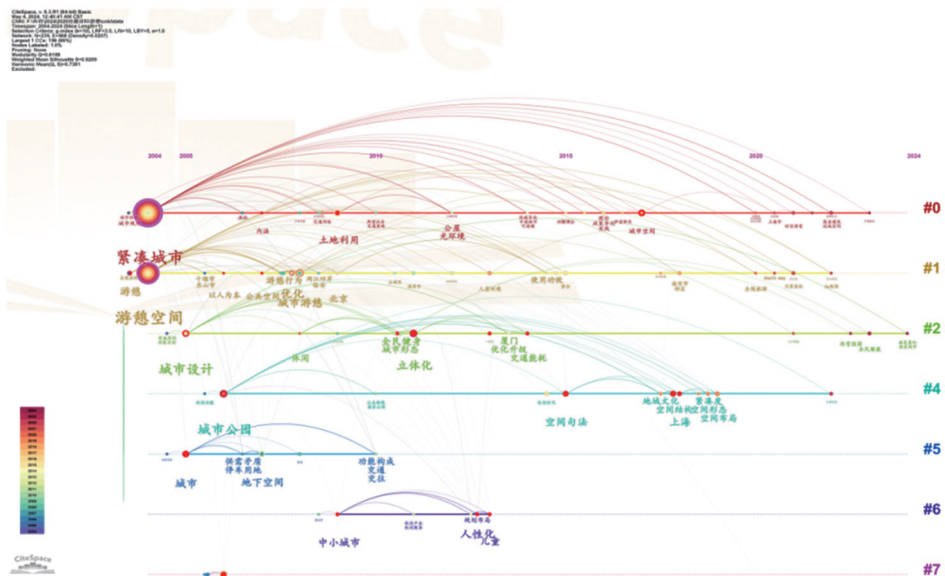

Fig.2   Graph of keyword co–occurrence

Note: #0: Compact city; #1: Recreation space; #2: Urban design; #4: Urban park; #5: Developed Western countries; #6: Small and medium-sized cities; #7: Planning.
Fig.3   The timeline map of keywords

spatial problems, while also bringing new challenges and opportunities for the design and management of urban recreation space.

The analysis on multiple theme co-occurrence shows that the research on three-dimensional urban recreation space is forming a multidisciplinary, multi angle, and multi-level research pattern. This cross fusion not only enriches the research content, but also provides more comprehensive and innovative ideas for solving practical problems.

5 Keyword burst analysis
5.1 Identification and meaning of burst terms

Keyword burst analysis is a method of identifying newly emerging themes or themes that have regain focuses in the research field. CiteSpace has identified 25 burst terms through the burst detection function, which show a significant increase in frequency during a specific time period, indicating a significant increase in their research popularity during that period. The recognition of burst terms is of great significance for understanding new and future trends in the research field. They may represent emerging research directions or new understandings and interpretations of existing research themes (Fig.5).

5.2 Relationship between burst intensity and research popularity

Burst intensity is an indicator that measures the degree to which the occurrence frequency of a keyword increases within a certain period of time, and it is closely related to research popularity. In the study, the high burst intensity of terms such as "city", "planning", and "three-dimensional" indicates that these themes are very active in research activities during the relevant time period. The burst intensity can reflect the level of attention a theme receives in the academic community and the potential impact it may have on the practical field.

5.3 Evolution of time series and research hotspots of burst terms

The analysis on the time series of burst terms can show the evolution of research hotspots over time. For example, terms such as "recreation," "city," and "planning" appeared in earlier years, while terms such as "compact city," "spatial justice," and "artificial intelligence" have only emerged in recent years, indicating that the research focus has gradually shifted from traditional urban planning and design to new fields such as compact city theory, social justice, and technological innovation. This evolution reflects the impact of socio-

economic development, technological progress, and changes in academic interests on the three-dimensional research field of urban recreation space.

Fig.4　Cluster diagram

6 Conclusion

This study provides a systematic research review based on bibliometrics and knowledge visualization, offering a new perspective for
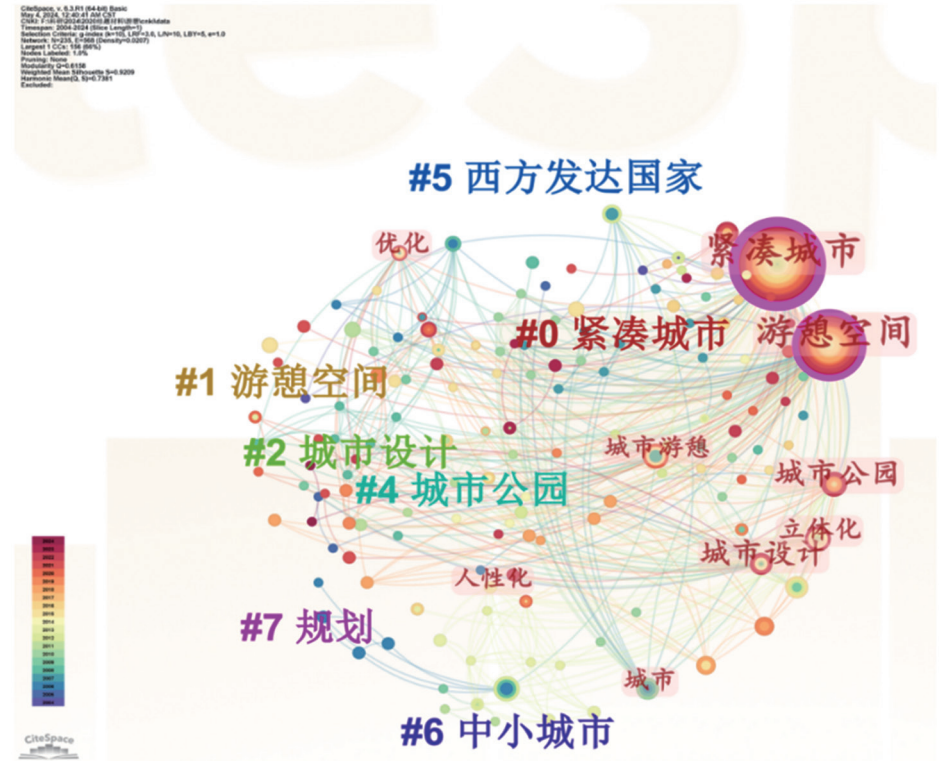
Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2004−2024
Recreation	2004	2.56	2004	2008	
City	2005	3.16	2005	2010	
Planning	2006	3.02	2006	2008	
People oriented	2006	1.13	2006	2007	
Optimization	2008	0.85	2008	2009	
Recreation	2008	0.81	2008	2011	
Land use	2009	2.23	2009	2012	
Small and medium-sized cities	2009	1.85	2009	2013	
Three-dimensional	2011	2.67	2011	2014	
Connotation	2007	0.96	2012	2014	
Humanization	2013	1.20	2013	2014	
Children	2013	1.07	2013	2020	
Integration	2013	0.93	2013	2016	
Transportation energy consumption	2014	1.04	2014	2016	
Spatial syntax	2015	1.85	2015	2018	
Public space	2007	0.99	2015	2016	
Compact city	2016	1.03	2016	2020	
Spatial structure	2018	2.32	2018	2019	
Shanghai	2018	1.97	2018	2022	
Recreation space	2018	1.74	2018	2019	
Urban park	2006	0.91	2018	2019	
City space	2019	1.19	2019	2020	
Optimization strategy	2017	1.85	2021	2022	
Urban design	2021	1.52	2021	2024	
Urban design	2005	0.75	2021	2022	

Fig.5　Keyword emergence

Table 2 Main keywords for clustering

Rank	Cluster name	Main keywords	Year	Number of keywords
1	Compact city	Compact city (49.32, 1.0E-4); Recreation space (27.63, 1.0E-4); Sustainable development (7.44, 0.01); Connotation (5.56, 0.05); City space (5.56, 0.05)	2013	121
2	Recreation space	Recreation space (26.66, 1.0E-4); Compact city (22.34, 1.0E-4); Urban recreation (5.46, 0.05); Recreation behavior (4.86, 0.05); Urban waterfront (4.86, 0.05)	2012	78
3	Urban design	Urban design (10.1, 0.005); Urban recreation space (9.56, 0.005); Three-dimensional (5.93, 0.05); Recreation space (5.33, 0.05); Fractal (4.75, 0.05)	2013	15
4	Urban park	Urban park (13.74, 0.001); Compact city (6.94, 0.01); Spatial structure (5.51, 0.05); Urban recreation system (4.53, 0.05); Baishui Lake(4.53, 0.05)	2015	16
5	Developed Western countries	Developed Western countries (6.78, 0.01); Theoretical mode (6.78, 0.01); Urban wetland (6.78, 0.01); Chongqing City(6.78, 0.01); Planning design principle (6.78, 0.01)	2008	15

understanding the research dynamics and trends in this field. The analysis on the trend of the number of published documents shows the dynamic changes in the field of three-dimensional research on urban recreation space over the past two decades. The fluctuating upward trend of the number of published documents is consistent with the timeline of promoting the concept of compact cities, indicating that urban planning concepts have a significant driving effect on academic research. The co-occurrence analysis of keywords and the construction of knowledge graphs highlight the central position of concepts such as "compact city," "recreation space," and "urban park," and the rise of emerging keywords such as "vertical city" and "spatial justice" reflects the evolution of research focus and the trend of interdisciplinary intersection. Cluster analysis further reveals the connections between the main research themes, pointing out the co-occurrence of compact cities with recreation space and urban design, as well as the evolution of these themes over time. The burst analysis identifies new hotspots in the research field, such as "city space" and "optimization strategy," which indicate possible directions for future research.

Although the study provides a literature analysis on the three-dimensional research field of urban recreation space, there are also limitations such as the comprehensiveness of literature data sources, the depth and time span selection of software text analysis. Subsequent research can further expand domestic and international data sources to obtain a more comprehensive perspective. The combination of artificial intelligence and big data can bring new insights into the three-dimensional design, management, and planning of urban recreation space.

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