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Review

Research Hotspots and Future Trends in Canal-Related Industrial Buildings

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Abstract: During the early stages of the Industrial Revolution, canals played a crucial role in facilitating the rapid development of factories. Despite economic downturns and the rise of alternative transportation towards the end of the last century, canals have been experiencing a resurgence in recent years, driven by the principles of sustainable development. To gain a deeper understanding of global academic research focus and current trends, this paper systematically reviews publications related to canal-related industrial buildings from 1997 to 22 January 2024. Using the bibliometric software CiteSpace 6.3.1, information such as countries, institutions, authors, keywords, and references from 96 selected articles in the Web of Science (WoS) database was visualized and analyzed. The results reveal that the current research hotspots in this field mainly focus on five clusters: "stakeholders", "green spaces", "conservation areas", "industrial heritage", and "energy-efficient reconstruction". The most popular research topics concerning canal-related industrial buildings are "urban renewal", "industrial heritage", "climate change", and "heritage tourism", with most themes closely linked to sustainable development. However, it is observed that there is still a lack of a systematic research framework in this field. Most studies originate from heritage management and conservation, landscape rejuvenation along canals, and canal water resource management, while systematic research on canal-related industrial buildings remains limited. Based on these findings, this study proposes future trends and potential research directions in this field, aiming to provide researchers with a comprehensive understanding of the status and to support the sustainable preservation and management of industrial buildings and heritage along canals with a more systematic research framework.

Keywords: canal; industrial heritage; industrial buildings; bibliometric analysis

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1. Introduction

The fate of territories largely depends on the condition of communication infrastructure. Its existence, nature, pattern, and speed determine the attractiveness and population density of a region. Among these infrastructures, waterways stand out as the most prominent transportation routes and geographical features. Throughout the 17th century, the development of transportation networks often expanded following the model of waterways [1]. The evolution of urban industry is similarly closely linked to efficient transportation, with canals playing a pivotal role during the pre-industrial period [2]. This stems from the industrial reliance on resources such as raw materials, energy, and transportation networks to produce goods and distribute them to broader markets [3]. Many industrial activities effectively utilized the hydraulic power of canals or transported raw materials to factories and products from factories to markets through canals [4,5]. Some factories even built specialized industrial canal systems [5]. By enabling large-scale, rapid, and cost-effective transportation of goods, canals accelerated the pace of the Industrial Revolution.

In addition to providing immense convenience for industry and transportation, canals also contributed to sustainable development in modern economy, agriculture, ecology, and energy [5,6]. As the canal system continued to expand, more factories gained strategic locations, allowing them to quickly benefit from the advantages brought by canal resources [7]. Consequently, these factory landscapes became some of the most vibrant visual indicators of urban economic development and prosperity during the 19th and early 20th centuries. However, over time and with changes in economic structures, along with the emergence of new global economic situations and transportation methods, canals gradually lost their original advantages. Traditional industrial areas along canals, unable to adapt to the new economic environment, faced transformation or closure, forming what is commonly known as "rust belts" [8]. These industrial remains have profound connections with cultural and natural environments, reflecting the characteristics of past manufacturing developments and defining today's environmental and landscape contexts [9]. They are products of urban realities occurring in specific social and temporal contexts [10]. With the increasing focus on industrial archaeology since the late 20th century, such architectural remains and canals have been recognized as industrial heritage with significant social, historical, and technological value. Particularly after the turn of the 21st century, the promulgation and promotion of a series of industrial heritage protection documents have led to a renewed appreciation for the value of historical industrial buildings and a deeper understanding of sustainable development principles, gradually recognizing canals and architectural heritage as important components of urban economic and cultural development [11,12]. Abandoned historical industrial sites and canal-related infrastructure not only serve as material evidence of urban development but also carry rich historical and cultural connotations [13]. Attention and reuse of these sites not only protect and materialize their memory, thereby promoting culture, education, and research [10], but also help people find a sense of belonging, satisfying the basic need for spiritual return [14], transforming them into part of cultural supply and repurposing them to provide new services to cities [15]. As a result, industrial buildings along canals have increasingly been viewed as sites for redevelopment and research, making positive contributions to urban transformation [16]. This research has attracted scholars from various disciplines, including architecture, civil engineering, water resources, marine engineering, environmental science, urban studies, and historical archaeology. Researchers from these fields have explored buildings along canals from multiple unique perspectives, such as ecosystem services, tourism, water governance, historical environments, collective memory, and modern architecture. However, current research exhibits some limitations, primarily evident in the lack of a systematic investigation into the comprehensive knowledge graph of industrial buildings along canals. Therefore, this paper employs knowledge graphs as an emerging method of literature analysis, aiming to provide a holistic and comprehensive description of the discipline for a better understanding of the knowledge structure and current research status. Especially as the literature on industrial buildings along canals continues to grow and new research themes emerge, understanding the academic evolution of these research topics holds important theoretical and practical significance. This paper tracks research hotspots and aims to answer the following questions:

Q1: How has the research focus on canal-related industrial buildings changed and developed?

Q2: What are the popular themes in existing research literature on canal-related industrial buildings?

Q3: What are the research trends and future directions concerning canal-related industrial buildings?

2. Materials and Methods

2.1. Data Collection

The Web of Science (WoS) has long been considered the most authoritative scientific literature retrieval tool, providing access to key scientific research fields [17] In this study,

we expanded the literature retrieval of the "Web of Science Core Collection" to include the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), and Conference Proceedings Citation Index (CPCI). The data was obtained from the library of the University of Bologna, Italy. To obtain comprehensive data, we tracked data up to 22 January 2024, and initially used the keyword combination ((((TS = (industrial building)) OR TS = (plant))) OR TS = (factory)) OR TS = (industrial)) AND TS = (canal)) OR TS = (artificial waterway)) NOT TS = (medicine), which yielded 3554 documents. Subsequently, we selected documents from SCIE, SSCI, A&HCI, and CPCI databases, excluding literature unrelated to canal transportation such as medicine, biology, and geology, for example, Dentistry or Surgery Medicine or Marine Freshwater Biology or Neurosciences or Cell Biology or Plant Sciences, resulting in 319 documents related to canal-related industrial building research. Finally, we conducted a comprehensive review of the abstracts of the 319 articles, further excluding articles discussing riverbeds, sediments, and other topics unrelated to buildings along canals, resulting in the extraction of 96 closely related documents, which were saved as plain text files. The content recorded, comprehensive records, and exported references were used for subsequent analysis (as shown in Figure 1).

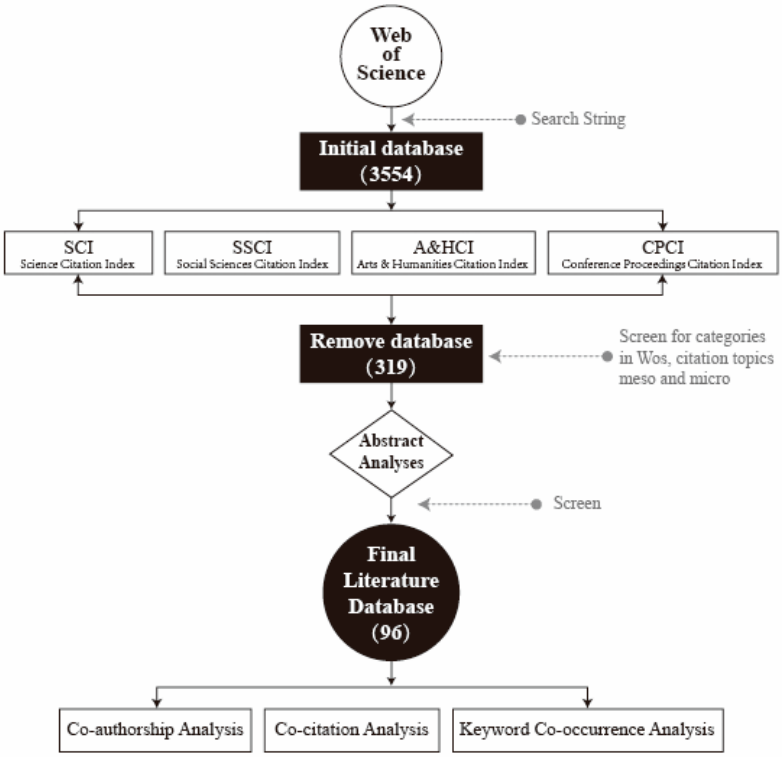

Figure 1. Framework for Literature Retrieval, Screening, and Bibliometric Analysis of Canal-Related Industrial Building Literature.

2.2. Research Method

This study employs CiteSpace (version 6.2.R4) as the primary bibliometric software. CiteSpace is widely used for literature data processing, with its main functions including visualization of knowledge graphs and analysis of research hotspots and emerging trends [18]. In the field of canal-related industrial building research, this software can clearly display information such as the number of documents, keywords, research categories, and research institutions, aiding in exploring the development and evolution of the field, prominent themes, and the association of relevant research units, thereby supporting in-depth analysis and understanding of current research hotspots and trends [19].

3. Data Result Analysis

In this section, CiteSpace is utilized to conduct a macroscopic analysis of the status and research trends in the field based on the basic information of the 96 articles collected, including publication year, journal, and authors. Furthermore, it addresses Q1.

3.1. Analysis of Publication Quantity

Figure 2 utilizes quantitative data provided by Web of Science (WoS) to analyze the publication years and trends of publications discussing canal-related industrial buildings. The data indicates that the earliest literature record dates to 1997. Overall, there are two peaks, with nine articles in 2019 and 10 articles in 2022. Specifically, from 1997 to 2007, the number of publications fluctuated relatively steadily, with an overall annual output not exceeding four articles. However, from 2014 to 2017, there was breakthrough growth, increasing from two to eight articles. From 2015 to 2024, the number of publications has not been less than five articles per year. The highest annual publication volume occurred in 2022, with 10 articles. No publications related to canal-related industrial buildings were found from 1–22 January 2024. However, overall, over the span of 27 years, publications related to canal-related industrial buildings have shown a steady growth trend year by year. This reflects continuous attention to the topic of canal-related industrial buildings, and the analysis of the gray index trend line in Figure 2 indicates that this growth is not only continuous but also gradually accelerating. This suggests that research and discussions on this topic will continue to increase in the future.

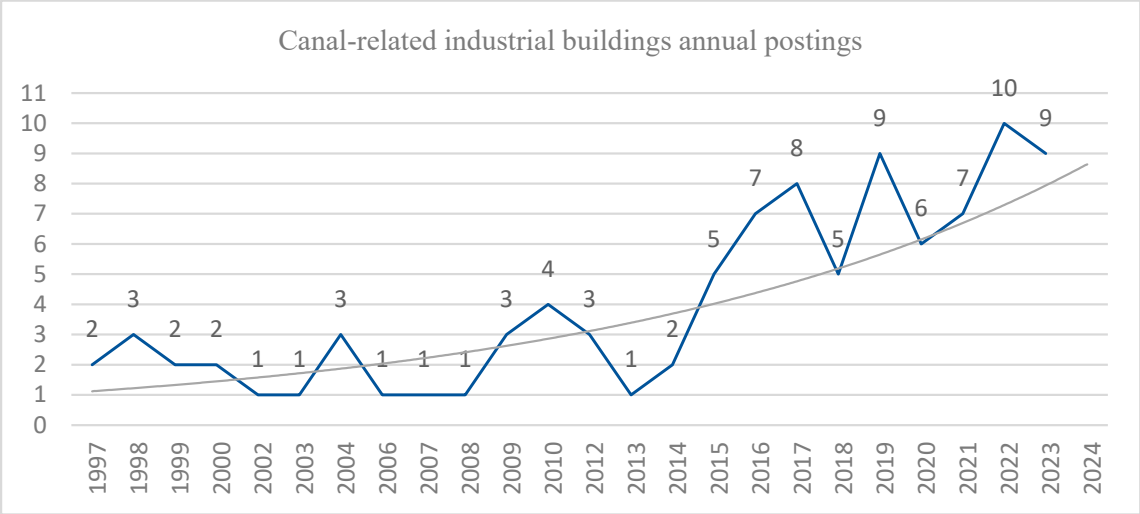

Figure 2. Annual trend analysis of publications in canal-related industrial building research.

3.2. Co-Authorship Analysis

Co-authorship is one of the most tangible and well-documented forms of scientific collaboration [20], including individuals, institutions, and countries. Co-authorship analysis facilitates the understanding of collaboration networks among different authors and reveals academic achievements in canal-related industrial building research from micro, meso, and macro perspectives [21].

3.2.1. Country Co-Authorship Analysis

Figure 3 presents a network analysis of country co-authors, revealing the dissemination of research on canal-related industrial buildings among various countries. When an article's authors are from different countries, the article will be assigned to each author's represented country. This is because research articles typically represent the collaborative efforts of multiple authors and institutions from different geographical regions [22]. Therefore, co-authorship analysis clarifies the national and international cooperation among authors

and the contributions of authors from different countries to the research. It also provides insights into the scope and impact of cooperation among different countries and regions in research. In this network, each node represents a country, and the size of the node is proportional to the number of publications from that country. The blue ring around the node represents higher betweenness centrality, indicating that these nodes are critical points linking different parts of the network. The thicker the blue ring, the higher the centrality of the node [23].

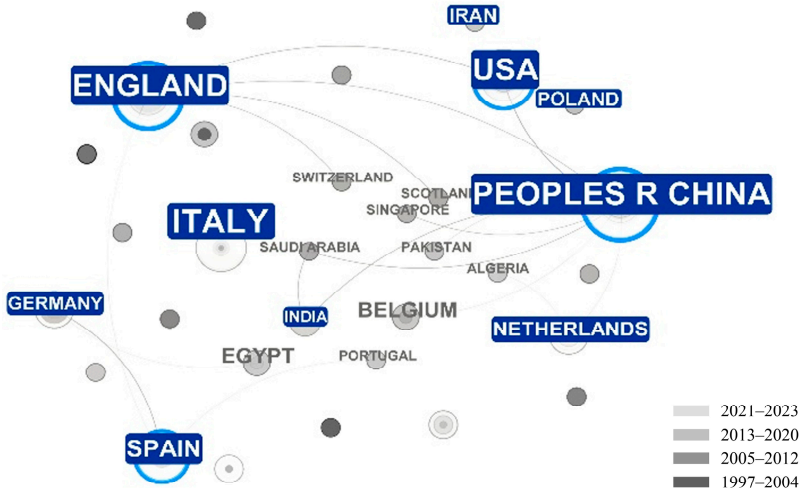

Figure 3. Network Diagram of International Collaboration in Research on Industrial Buildings along Canals.

According to the retrieved data, the global research network on canal-related industrial buildings consists of 31 countries, with the top 10 countries ranked as shown in Table 1. Among them, China (17 articles) has the highest number of publications. This is followed by England (15 articles), the United States (15 articles), Italy (12 articles), Spain (8 articles), and The Netherlands (5 articles), indicating that these countries dominate research on canal-related industrial buildings globally. Four countries, including China, the United States, England, and Spain, have blue ring nodes, indicating that these four countries play a crucial role in the research field of canal-related industrial buildings among the 31 countries. It is noteworthy that although Italy has a high number of publications, the centrality of Italy's 12 articles in canal-related industrial building research is 0, indicating that scholars in Italy are more independent in their research in this field. Additionally, we found that these top-ranking countries all have mature canal systems, such as China's Grand Canal [24], the Erie Canal in the United States [25], the Manchester Canal in England [26], the Birmingham Canal, and the Grand Canal in Italy. The canal system provides sufficient support for local research and a more convenient research environment, thereby promoting research on the theme of canal-related industrial buildings.

Moreover, international and national-level policy support can promote public attention to this field. At the international level, the World Heritage Experts Meeting of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) in 1994 emphasized the importance of canals and proposed methods to assess their economic, social, and landscape values through technology, such as canal-related buildings and technology, industrial development, and population mobility along canals. These authoritative research results promote the progress of research and academic support in canal-related industrial building research and facilitate experience exchange and sharing among different countries. At the national level, the United States legislated the National Canal Heritage Corridor (the Illinois and Michigan Canal National Heritage Corridor) as early as 1984, linking canals and industry to maintain balance [27]. The World Heritage Experts Meeting on Canal Heritage held by UNESCO in 1994 mentioned that the importance of canals can be verified through technology and demonstrated through a series of ways to reflect

economic, social, and landscape values [28]. In England, the Greater Manchester Canals Heritage Partnership Agreement (HPA) proposed by Canal & River Trust in 2014 further emphasizes the importance of canals to the local area. The agreement explicitly states that the canals in the Manchester area have high-value historical environments and encourages sustainable development and maintenance. This demonstrates the investment and support of governments and relevant organizations in the heritage of canal-related buildings [29] In China, the "Regulations on the Protection of China's Grand Canal World Cultural Heritage" promulgated in 2016 and the "Implementation Plan for the Protection, Inheritance, and Utilization of the Grand Canal Culture in the 14th Five-Year Plan" proposed in 2021 provide guiding documents for the development of canal culture. These documents explicitly mention the excavation and overall protection of valuable architectural relics and the promotion of the formation of green ecological corridors [30,31]. The release of these policies and documents not only provides support for the protection and management of canal cultural heritage in terms of technology and systems but also stimulates more researchers' interest in canal-related topics. This driving effect further promotes more research work, injecting new momentum into the academic and scientific aspects of this field and providing positive support for the sustainable development of canal-related cultural heritage in various countries.

Table 1. Top 10 Countries in Research on Industrial Buildings along Canals.

Counts	Centricity	Year	Country
17	0.34	1999	People's Republic of China
15	0.29	2000	England
15	0.26	1997	USA
12	0	1998	Italy
8	0.17	2015	Spain
5	0.06	2010	Netherlands
3	0.06	1997	Germany
3	0	2013	Poland
3	0	2009	Iran
3	0	2009	India

3.2.2. Institutional Co-Authorship Analysis

This paragraph maps and visualizes the institutional collaboration relationships in the research field of canal-related industrial buildings. Similar to the analysis of country co-authors, the size of the nodes indicates the number of publications. Figure 4 and Table 2 display the top 10 academic institutions in terms of the number of publications on canal-related industrial buildings. From the graph, it is evident that most institutions in the network appear to be independent, without significant connecting relationships. This indicates that cooperation among institutions is not comprehensive enough, and institutions tend to collaborate more with institutions from the same country. Additionally, due to the refinement of research topics, the limited research sample size results in a relatively small and uniform distribution of publications allocated to individual institutions. Among them, the institutions with the highest publication volume are the University of Bologna in Italy (three articles) and Southeast University in China (three articles). The institutions of Zhejiang University, the University of Padua, the University of Manchester, the Universidad de Castilla-La Mancha, Jiangsu International Urban Planning Design, Delft University of Technology, the Chinese Academy of Sciences, and the Canal & River Trust each have two articles. Among the top ten institutions, the University of Bologna and the University of Padua are located in northern Italy, with a total of five published papers. Their research revolves around the Milan artificial waterway and research related to the Venice Canal [32–34]. The four Chinese institutions collectively published nine articles, all focusing on research topics related to the Grand Canal of China and industrial buildings. These include segments of the Grand Canal in China and Hangzhou [35,36], and these

four institutions are located near the Grand Canal in China. Among the top ten research institutions, England occupies two positions, one being the University of Manchester and the other being the largest waterway charity organization in the ENGLAND, the Canal & River Trust, with a cumulative total of four articles. Established in 2012, the Canal & River Trust is the largest waterway charity organization in the ENGLAND, dedicated to maintaining a network of canals and navigable rivers spanning 2000 miles. The organization has conducted surveys of buildings around canals, counting over 2700 protected buildings, 50 listed ancient monuments, and 4 UNESCO World Heritage Sites Along British canals. Through discussions on canal heritage and industrial buildings, the organization hopes to attract more attention to canal architecture. In these four articles, discussions primarily revolve around the Manchester Canal and the work completed by the Canal & River Trust in managing and protecting buildings [37,38]. Universidad de Castilla-La Mancha is an academic institution in Spain that ranks in the top ten institutions in terms of the number of publications with two articles. The institution primarily focuses on research themes related to modern roads proposed by UNESCO, including discussions on inland water transportation in canals and industrial archaeology-related buildings [39,40]. Delft University of Technology in The Netherlands published two studies. One revolves around pollution issues in the ecological environment caused by factories near the canals in Skikda port in the northeastern Algerian city on the Mediterranean coast [41,42]. The other study is a collaborative effort with Tianjin University in China, focusing on research results related to the architectural heritage around the Tianjin section of the Grand Canal in China.

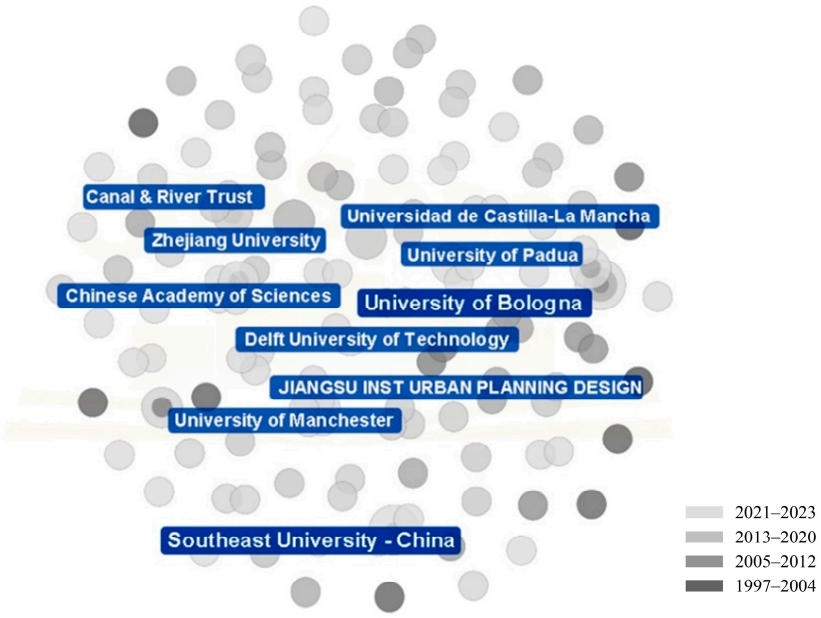

Figure 4. Institutional Collaboration Network Map in Research on Industrial Buildings along Canals.

Table 2. Top 10 Institutions in Research on Industrial buildings along Canals.

Counts	Year	Institutions
3	2003	University of Bologna
3	2015	Southeast University—China
2	2012	Zhejiang University
2	2010	University of Padua
2	2002	University of Manchester
2	2016	Universidad de Castilla-La Mancha
2	2020	Jiangsu Inst Urban Planning Design
2	2022	Delft University of Technology
2	2016	Chinese Academy of Sciences
2	2015	Canal & River Trust

Overall, most institutions primarily focus their research efforts on canals within their respective nations, with minimal cross-border collaboration facilitated by international exchanges. Additionally, our investigation reveals a close nexus between the top ten institutions and the canals themselves. Notably, a significant portion of the core research emanates from academic entities closely intertwined with and situated in proximity to canal resources. For instance, the Moline Canale flows into the urban area of Bologna [43] the locale of the University of Bologna (Count3). Similarly, Parma University benefits from its proximity to the Venetian Grand Canal and its surrounding urban areas, rich in canal resources [44] (Count 2). The University of Manchester, situated near the Manchester Ship Canal, and the Canal & River Trust, located in the vicinity of Regent's Canal in London, also contribute significantly to canal-related research [44,45] (Count 2 each). Moreover, among the top ten Chinese institutions in terms of research output, four are situated near the Grand Canal of China. Furthermore, a substantial portion of their pivotal research originates from academic institutions deeply intertwined with canal resources and situated near them, as illustrated in Figure 5. This underscores the acute attention these institutions pay to the local geographical milieu and resources during their research endeavors, as well as their contributions to the development and cultural heritage preservation of their respective national canal regions.

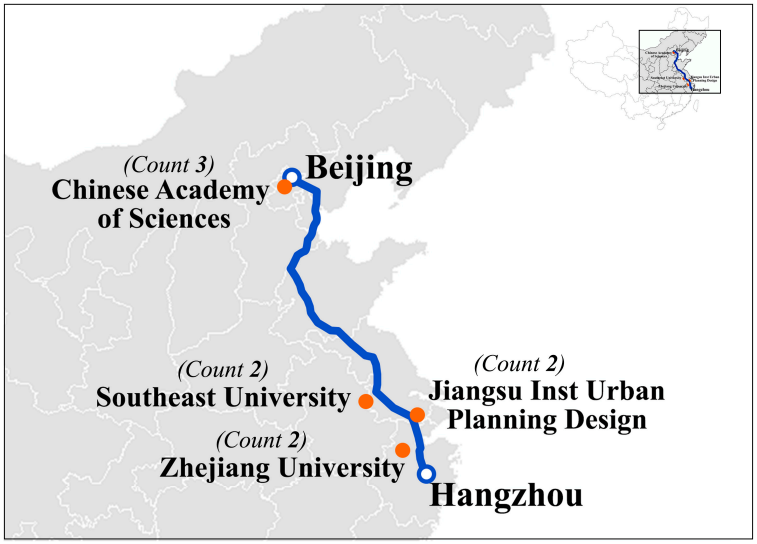

Figure 5. Among the top ten institutions, four institutions from China are all located near the Grand Canal Heritage.

3.2.3. Author Co-Authorship Analysis

Figure 6 illustrates the collaboration network of the top 10 authors in the field of research on canals and industrial buildings. This network was generated by selecting appropriate units, setting thresholds, and excluding isolated nodes, with the size of the nodes proportional to the number of papers authored by each author [46]. A total of 176 authors participated in research on topics related to canals and industrial buildings, contributing to a total of 96 papers. As shown in Figure 6, the entire network consists of a series of isolated small sub-networks without forming large-scale clusters and connections. This indicates that authors in the research field related to canals and industrial buildings tend to collaborate in small-scale cooperative groups, lacking broader exchanges with each other. In Table 3, among the top 10 scholars, Spanish scholar Rita Ruiz published two academic papers as the first author in research related to canals and industrial buildings. British scholar Johan Woltjer published one paper as the first author and one as the second author on topics related to canals and industrial buildings. The number of related studies by other scholars is one, and they have only completed one academic research project related to canals and industrial buildings by collaborating with other scholars. This once again

emphasizes that authors in this research field tend to assist in small-scale cooperative groups, lacking broader collaboration and exchanges, and lacking sustainability in research trends related to the research topic.

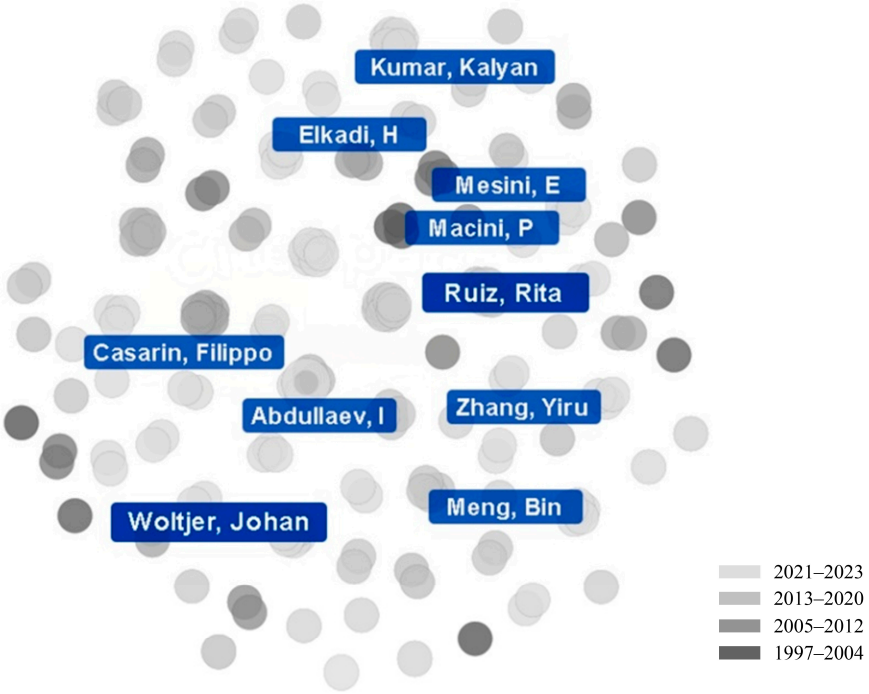

Figure 6. Co-authorship network diagram of research on canal-related industrial buildings.

Table 3. Co-authorship in the Top 10 Research on Canal-Related Industrial buildings.

Counts	Year	Institutions
2	2016	Ruiz, Rita
2	2014	Woltjer, Johan
1	2018	Zhang, Yiru
1	2016	Kumar, Kalyan
1	2021	Elkadi, H
1	2023	Meng, Bin
1	2003	Macini, P
1	2003	Mesini, E
1	2004	Abdullaev, I
1	2021	Casarin, Filippo

3.3. Co-Citation Analysis

The analysis of co-citations among authors provides insights into the collective contributions of research entities to the field of industrial buildings related to canals. However, accurately reflecting the specific contributions of journals, literature, and authors to this domain can be challenging [47]. Co-citation relationships are defined as the joint citation of two or more journals, publications, or authors in a third-party document. Therefore, in this section, we employ this method to identify the relationships and structures among journals, literature, and authors in the research topic.

3.3.1. Journal Co-Citation Analysis

The analysis of journal co-citation offers valuable insights into the structural organization of academic domains primarily disseminated through scholarly journals [48]. Utilizing the CiteSpace tool, we constructed Figure 7 for elucidation, where nodes represent academic journals and links denote co-citation relationships between journals. The size of

nodes reflects the frequency of journal citations, with larger nodes indicating higher significance within the research domain. Additionally, the blue rings surrounding nodes signify higher betweenness centrality, indicating pivotal nodes connecting different segments of the network. The thickness of the blue rings reflects the degree of betweenness centrality, with thicker rings indicating greater importance in the overall network connectivity. This visualization method enables us to identify the associations and hierarchical structures among academic journals more clearly, thereby inferring the organization and influence patterns within the academic domain [49]. By analyzing nodes and links within the graph, we can also unveil the relative positions, collaborative relationships, and critical pathways of academic journals in the research domain.

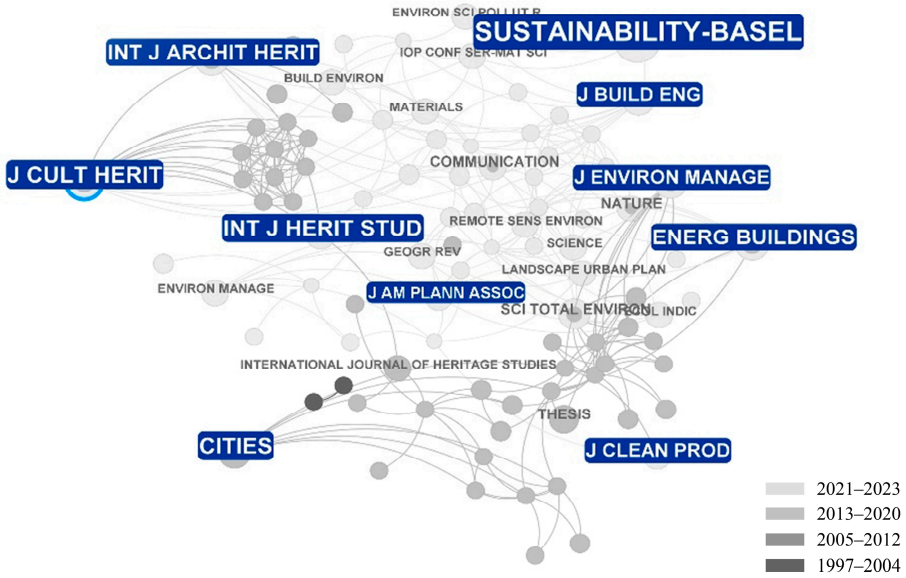

Figure 7. Network analysis of journals cited in research on canal-related industrial buildings.

A total of 96 papers on industrial buildings related to canals were indexed in 33 journals, predominantly in authoritative outlets (as shown in Table 4). Among these, the most frequently cited journal is "Sustainability" (9), an international journal focusing on human-environmental, cultural, economic, and social sustainability, providing a broad perspective and framework for research in the field of industrial buildings related to canals. Subsequently, journals ranked 2nd, 3rd, and 4th have a citation count of six each. "International Journal of Heritage Studies" is an interdisciplinary scholarly reference journal primarily addressing leading and cutting-edge international resources in heritage politics, culture, management, and economics. "Journal of Cultural Heritage (J CULT HERIT)" mainly focuses on cultural heritage preservation and awareness. "Cities" is a journal focusing on urban politics, theories, governance, and smart cities. Following these, journals ranked 5th and 6th in citation count are "ENERG BUILDINGS" and "International Journal of Architectural Heritage (INT J ARCHIT HERIT)". The former concentrates on building energy usage and efficiency, while the latter emphasizes research on historical buildings and structures as well as papers related to architectural restoration. The remaining four journals in the top ten by citation count, each with a count of four, are "Journal of the American Planning Association (J AM PLANN ASSOC)", primarily focusing on planning and urban development perspectives; "Journal of Cleaner Production (J CLEAN PROD)", devoted to research and practices on clean production, environment, and sustainable development; "Journal of Environmental Management (J ENVIRON MANAGE)", associated with managing environmental systems and improving environmental quality; and "Journal of Building Engineering (J BUILD ENG)", covering scientific and technological aspects related to the entire lifecycle of building environments. Among the top ten journals, "Journal of Cultural Heritage" exhibits a higher degree of centrality, indicating its pivotal position and influence

within the academic journal network. This underscores the importance and influence of this journal in the field of industrial buildings related to canals. In contrast, although the journal "Sustainability" has a higher citation count and significant influence within the research domain, its centrality within the academic journal network is relatively lower. Overall, these journals cover multiple domains, including sustainable development and environmental management, cultural heritage preservation, architecture, and energy, as well as urban planning. This reflects the interdisciplinary and comprehensive nature of research in industrial buildings related to canals.

Table 4. Top 10 journals cited in research on canal-related industrial buildings.

Counts	Centricity	Year	Journals
9	0	2021	SUSTAINABILITY-BASEL
6	0.03	2017	INT J HERIT STUD
6	0.14	2016	J CULT HERIT
6	0.11	2016	CITIES
5	0.07	2017	ENERG BUILDINGS
5	0.05	2017	INT J ARCHIT HERIT
4	0.04	2014	J AM PLANN ASSOC
4	0.02	2019	J CLEAN PROD
4	0.02	2019	J ENVIRON MANAGE
4	0.02	2022	J BUILD ENG

3.3.2. Literature Co-Citation Analysis

The analysis of co-citations among references or articles is invaluable for evaluating the developmental patterns within a research field. By selecting representative studies for analysis and constructing a co-citation network of literature, we can effectively unveil the structure and dynamics of specific domains [50]. In this network, nodes represent different cited documents, and the thickness of the edges signifies the strength of co-citation between documents, while the size of nodes symbolizes the importance of documents. Closer proximity between two nodes indicates greater similarity between the cited literature [51].

As depicted in Figure 8 and Table 5, the two most co-cited articles are by Raitz K. (2012) [52] and Ruiz R. (2014) [53], each referenced by two other studies related to industrial buildings associated with canals. The article by Raitz K. (2012) discusses the historical landscape along the Amesville Road in America, which meanders along the Ohio River. This paper discusses conservation of the heritage corridor based on a case study on historic towns along the Beijing–Tianjin section of the Grand Canal. Through fieldwork in more than ten towns and districts, the author finds out that material remains in the ancient towns are very rich, diverse cultures have a close relation to the canal and the natural environment is so important to the sustainable development of this area. The paper points out that the ancient remains have significant historic and cultural value and the Grand Canal implies great ecological value. It stresses on authenticity and integrity in heritage conservation and proposes the combination of heritage conservation and ecological protection [52]. It describes the development of this route, examines its impact on the evolution of transportation technology and the use and abandonment of other channels, and explores its role in shaping the broader American landscape [53]. This article is cited in discussions about the heritage value of roads [40] and when elaborating on the "demolition of many historic public works to make way for new construction" [54]. The other article, "Identification and assessment of engineered road heritage: A methodological approach" by Ruiz R. (2014) [53], is cited twice. Ruiz's work is referenced when explaining the increasing tendency of literature to consider roads as large-scale heritage [40] and when discussing how "ruins are considered part of the development of science and technology, revealing the processes and theoretical bases related to the construction of historical landscapes" [55].

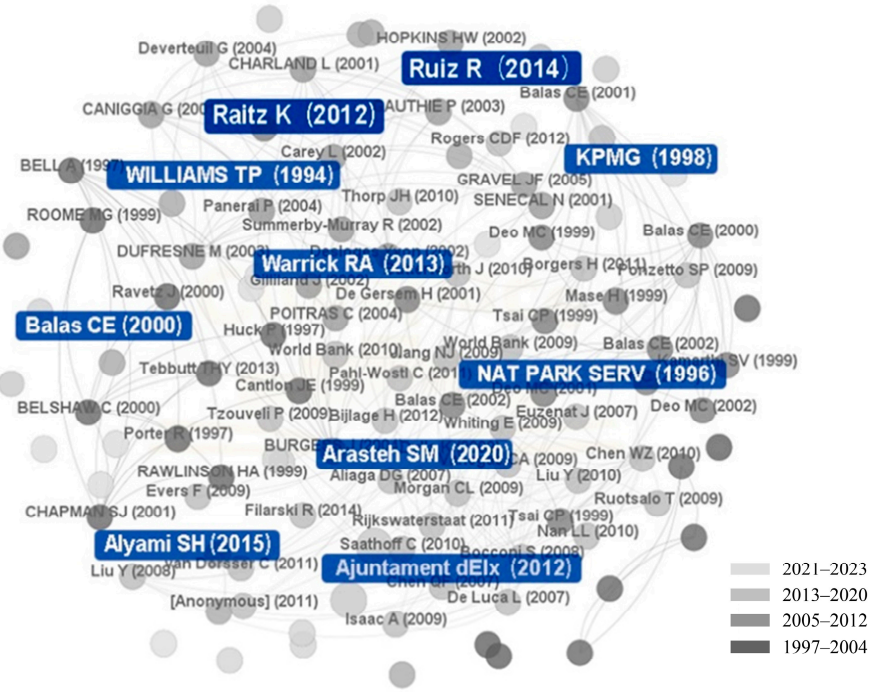

Figure 8. Network analysis of citations in research on canal-related industrial buildings.

Table 5. Top 10 Cited Documents in Research on Canal-Related Industrial Buildings.

Counts	Year	Documents
2	2012	Raitz K, 2012, KENTUCKYS FRONTIER HIGHWAY: HISTORICAL LANDSCAPES ALONG THE MAYSVILLE ROAD, V0, P1
2	2014	Ruiz R, 2014, J CULT HERIT, V15, P36, DOI 10.1016/j.culher.2013.01.001
1	1994	WILLIAMS TP, 1994, J CONSTR ENG M ASCE, V120, P306, DOI 10.1061/(ASCE)0733-9364(1994)120:2(306)
1	2020	Arasteh SM, 2020, ENVIRON EARTH SCI, V79, P0, DOI 10.1007/s12665-020-09268-w
1	1996	NAT PARK SERV, 1996, HDB 140 LOW STOR IND, V0, P0
1	1998	KPMG, 1998, KPMG PROJ APPR REP E, V0, P0
1	2000	Balas CE, 2000, COAST ENG J, V42, P57, DOI 10.1142/S0578563400000043
1	2012	Ajuntament dElx, 2012, PROYECT REH PUEST VA, V0, P0
1	1993	Warrick RA, 1993, CLIMATE AND SEA LEVEL CHANGE: OBSERVATIONS, V0, P0
1	2015	Alyami SH, 2015, SUSTAIN SCI, V10, P167, DOI 10.1007/s11625-014-0252-x

Apart from these two articles, the number of co-cited references is relatively low, and thus, we did not conduct separate discussions on them. However, from the research focus of the top ten co-cited articles, it is evident that these articles do not directly address canal-related architecture but rather pertain to topics such as roads [54,55], building costs [56], groundwater resources [57], and assessment methodology [58,59]. Although these articles do not directly focus on canal-related architecture, they are indirectly related to it. Additionally, it is noteworthy that the majority of highly co-cited references in the top two articles are from Ruiz R. This indicates that research on industrial buildings related to canals is primarily concentrated within individual units and involves mutual referencing. Furthermore, more studies consider canals as aquatic branches of roads for research. This also reflects that research on industrial buildings related to canals has not yet formed a systematic independent study and remains relatively small in scale.

3.3.3. Authors Co-Citation Analysis

The analysis of co-citation among authors not only reveals the distribution of highly cited authors within an academic field, but also identifies scholars who have had the most profound impact on the field. Furthermore, it allows us to understand the similarity between researchers and the distribution of their research topics within the disciplinary domain [60]. In this study, we utilized CiteSpace to construct Figure 9, where each node represents a scholar, and the links between nodes represent their co-citation relationships. The size of nodes indicates the frequency of citations received by authors, while the distance between nodes reflects the frequency of co-citations between two scholars. Larger nodes signify higher importance for the authors, while closer distances indicate greater similarity in research directions between two scholars [61].

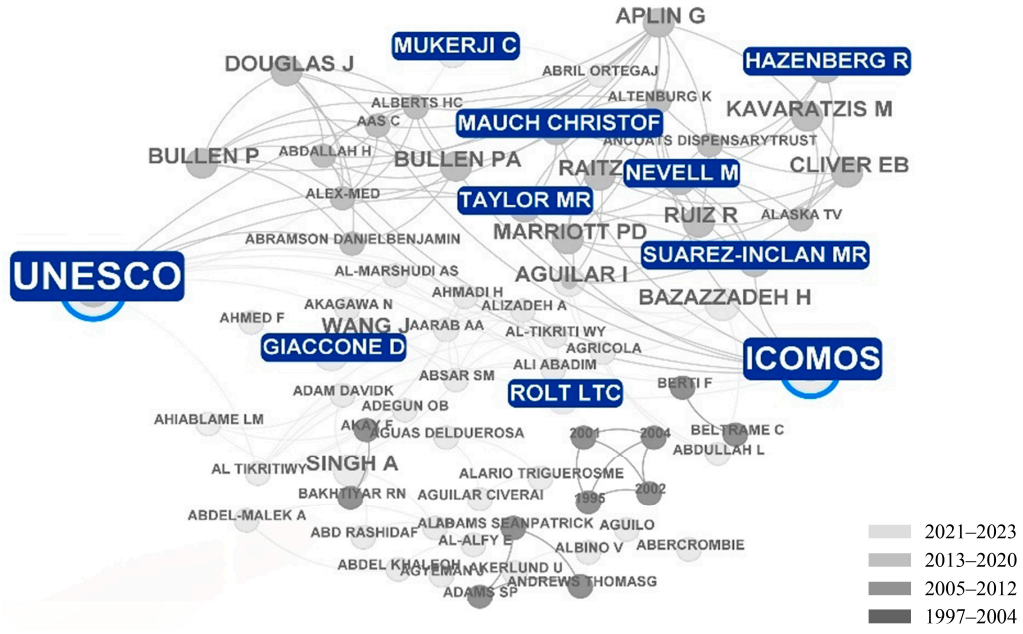

Figure 9. Author co-citation analysis network map for canal-related industrial building research.

In Figure 9 and Table 6, the largest node represents UNESCO, with the highest betweenness centrality of 0.32. This indicates that publications from UNESCO hold significant authority and importance and are widely cited in studies related to canal-associated architecture. UNESCO, the United Nations Educational, Scientific, and Cultural Organization, is dedicated to promoting world peace and security through international cooperation, notably through the World Heritage List, which it has established for the protection and preservation of cultural and natural heritage. Additionally, UNESCO has formulated numerous standards and legal instruments for heritage conservation, such as the 1972 Convention concerning the Protection of the World Cultural and Natural Heritage, aimed at ensuring the identification, protection, conservation, presentation, and transmission to future generations of cultural and natural heritage of outstanding universal value.

Ranked second is ICOMOS, with a centrality of 0.11, highlighting its significant role in research related to canals and industrial buildings. ICOMOS, the International Council on Monuments and Sites, is a non-governmental advisory body to UNESCO, dedicated to promoting the conservation, protection, use, and enhancement of monuments, building complexes, and sites. ICOMOS has issued numerous regulations, ethical principles, and charters related to the architectural heritage sector, such as the Venice Charter (1964) [62], Amsterdam Declaration (1975) [63], Florence Charter (1982) [64], Washington Charter (1987) [65], Burra Charter (1999) [66], and Dublin Principles (2011) [3], which provide important research support for the protection of industrial architectural heritage.

Table 6. Top 10 co-cited authors of canal-related industrial building research.

Frequency	Centrality	Year	Author
6	0.32	2016	UNESCO
4	0.11	2017	ICOMOS
2	0	2017	MAUCH CHRISTOF
2	0.4	2016	SUAREZ-INCLAN MR
2	0.01	2021	MENGLANDERJI C
2	0.06	2016	NEVELL M
2	0.04	2016	TAYLOR MR
2	0	2016	HAZENBERG R
2	0	2022	GIACCONE D
2	0	2017	ROLT LTC

Furthermore, the third to tenth most-co-cited authors each have two papers. Of note, Nevell M exhibits relatively high betweenness centrality compared to other scholars, at 0.06. Dr. Mike Nevell is a seasoned industrial, architectural, and landscape archaeologist and the chairman of the Industrial Archaeology Association. With over 30 years of experience, he has authored 48 works covering various fields such as industrial archaeology, architectural archaeology, climate change and heritage, community archaeology, and archaeology of the Manchester region. Much of his research focuses on industrial heritage, architectural heritage, and heritage in the Manchester region, making significant contributions to research on heritage conservation in canal-related industrial buildings. Another scholar with a betweenness centrality of 0.01 is Chandra MEnglanderji, who primarily focuses on the material aspects of human culture and exchange processes—from architectural environments to popular cultural artifacts. She authored "Territorial and Technological: The Case of the Midi Canal", which insightfully explores the mysteries of the canal passing through southwestern France and its surprising political significance.

The remaining six scholars, although less central, are widely cited by researchers studying canal-related industrial buildings. Among them, Christof Mauch focuses on American cultural history and transatlantic studies, publishing "Rivers in History: Perspectives on Waterways in Europe and North America", which delves into the situation of rivers and canals in 19th and 20th-century Europe and North America. Mr. Suárez-Inclán is concerned with the conservation of sustainable cultural heritage. Mr. Taylor specializes in creative industry research. R. Hazenberg focuses on the sustainable future social impacts and innovation of industry and enterprises. LTC Rolt focuses on industrial, railway, and engineering history. Domenico Giaccone specializes in the structural analysis of architectural heritage.

These scholars have played key roles in advancing research on canal-related industrial buildings, providing significant support for the development of this field, and promoting academic exchange and collaboration. Their work not only elucidates the knowledge structure within this field but also highlights influential scholars making significant contributions in various directions, thereby deepening our understanding of this domain.

3.4. Research Hotspot Analysis

This section employs keyword contribution analysis and clustering analysis to elucidate the relationships between keywords and identify current research hotspots [67], addressing Research Question 2 (Q2).

3.4.1. Keyword Co-Occurrence Analysis

The keywords in publications summarize the research content of each publication, relating to the research objectives and methods, aiming to provide information about the core content of the articles. The term "hot research topics" refers to the current research areas that are predominantly focused on by the scientific community [68]. Co-occurrence analysis of keywords, as a powerful analytical tool, explores the significant themes related to canal-related industrial buildings by analyzing the frequency and centrality of co-occurring

keywords [69]. To explain the research theme, we conducted keyword co-occurrence analysis. As shown in Table 7, we obtained the top 10 keywords and categorized them into the following two major research methods:

Table 7. Top 10 Keywords Ranked by Count and Centrality.

Ranking	Counts	Centricity	Year	Keyword
1	5	0.02	2015	industrial heritage
2	4	0	2012	the grand canal
3	3	0.01	2004	water management
4	3	0	2016	renovation
5	2	0	2019	design
6	2	0	2016	Chinas grand canal
7	2	0.01	2012	heritage
8	2	0.01	2019	heritage tourism
9	2	0	2017	adaptive reuse
10	2	0	2015	heritage management

In terms of research methods, "renovation" is the most commonly used research method in studies related to canal-related industrial buildings, often referring to revitalizing defunct industrial landscapes or spaces along the canal through renovation means [70]. Additionally, design is also a significant method, intervening and shaping the development of surrounding areas effectively through designing and planning the landscapes along the canal [71]. In terms of industrial building renewal, the method of "adaptive reuse" is also employed to help determine the best utilization of buildings, thus receiving extensive research attention [72]. Moreover, methods from management studies are also applied in canal-related industrial buildings, primarily focusing on two aspects: canal "water resource management" and "heritage management", with water resource management concentrating on the rational utilization of canal water resources and heritage management involving the maintenance and management of industrial historical building assets within the protected areas.

In terms of research objects, "industrial heritage" is the core research object in studies related to canal-related industrial buildings, followed by the broader term "heritage". Industrial heritage refers to industrial cultural relics with historical, technological, social, architectural, or scientific value. These relics include buildings and machinery, workshops, mills and factories, mines, processing and refining sites, warehouses and stores, places for energy production, transmission, and use, transportation and all its infrastructure, as well as places for social activities and housing, religious worship, or education related to industries [73]. Especially since the 1970s, industrial centers in North America and Europe have lost reasons for economic existence, resulting in many industrial buildings being abandoned [74]. These abandoned buildings represent the material heritage of the Industrial Revolution, recording the historical development of human industrialization. Gradually, people began to recognize the rich historical and unique cultural value embodied in these heritage sites, leading industrial heritage to become the focus of research related to canal-related industrial buildings.

In specific canal studies, "The Grand Canal" is a key research focus, mainly referring to the Grand Canal in China in the literature, with one article referring to the Grand Canal in Venice [33]. As one of the most important transportation channels in Chinese history, China's Grand Canal possesses abundant industrial heritage resources and cultural heritage. Although some studies refer to it as "the Grand Canal" or "China's Grand Canal", it has not diminished the research enthusiasm but has become a focal topic in the field. Additionally, "heritage tourism" is a relatively new hot keyword, and its research field is highly concerned with exploring how to mainly concentrate on the development and utilization of heritage resources, restoring heritage as tourism resources for urban development [75].

These research objects and methods are significant in the study of canal-related buildings, not only contributing to a deeper understanding of the history and culture of canal-related industrial buildings but also providing effective ways to address related issues.

3.4.2. Keyword Cluster Analysis

To analyze current trends and themes in research related to canal-associated industrial buildings, we employed the LLR algorithm in CiteSpace for keyword cluster analysis. This method allows us to extract clusters of keywords from relevant literature and generate descriptive labels for each cluster. Notably, these labels reflect cluster characteristics rather than serving as their names [76], facilitating comprehension of research outcomes and enhancing communication with a wider audience. Figure 10 illustrates that keywords in research on canal-associated industrial buildings primarily cluster around #0 stakeholders, #1 green space, #2 conservation areas, #3 industrial heritage, and #4 energy-saving reconstruction.

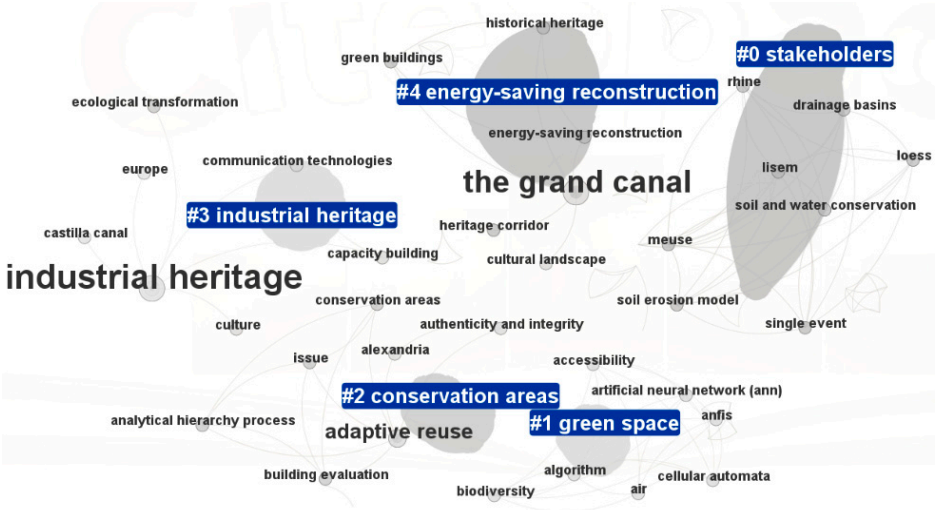

Figure 10. Keywords co-citation network diagram for canal-related industrial building research.

The largest cluster, "#0 Stakeholders", encompasses keywords closely associated with canals such as the Rhine, Lisem, Loess, and Meuse. Stakeholders play pivotal roles in projects, influencing conservation, development, community engagement, and economic growth, collectively driving sustainable heritage conservation. Researchers in this cluster consider stakeholder perspectives to balance conflicting interests. For instance, Buckman (2014) emphasized the importance of key stakeholders' input in the feasibility of developing heritage buildings along the 181-mile canal corridor in Phoenix, Arizona [77]. Hong and Chen (2017) evaluated the adaptability of historically significant buildings in the World Heritage Grand Canal area in Hangzhou, China, proposing an assessment model to prioritize adaptive reuse buildings and allocate public funds effectively [78]. This model aims to facilitate broad public participation in decision-making processes regarding adaptive reuse of historical buildings to meet stakeholders' needs. Additionally, Hijdra, Arts, and Woltjer (2014) underscored the significance of addressing funding issues and conflicting stakeholder interests when discussing reinvestment and management of abandoned canal waterways [79].

The "#1 Green Space" cluster includes keywords such as accessibility and artificial neural networks, indicating scholars' heightened focus on the sustainability of spatial environments. For instance, Labib (2019) utilized artificial neural networks (ANN) and adaptive neuro-fuzzy inference system (ANFIS) algorithms, along with statistical models, to predict the likelihood of green or gray transformation of derelict sites and vacant land along canal corridors based on Manchester's ecological, environmental, and social standards [80]. Zhao (2022) empirically analyzed the inherent connections of settlement spatial environments along the Tianjin section of the Grand Canal [42], confirming the positive role of ecological

factors in various aspects of life, production, accessibility, and socio-cultural aspects within these settlements. Furthermore, Comino (2020) explored the significance of renewable energy and industrial heritage conservation transforming into sustainable urban water management, exemplifying ecologically sustainable design for small hydropower plants along Turin's "Regio Parco" canal to facilitate effective management and utilization of urban water resources [71]. Taraszkiewicz and Nyka (2017) noted that large urban spaces are often situated in brownfield and post-industrial spaces closely related to canals, rivers, and other waterways, providing ideal conditions for additional recreational functions like designing parks and other green spaces [81].

The "#2 Conservation Areas" cluster includes keywords such as authenticity and integrity, adaptive reuse, and building evaluation, closely related to conservation methods for heritage sites. For instance, H. Li (2012) emphasized the importance of maintaining authenticity and integrity in historical building conservation along the Beijing–Tianjin section of the Grand Canal in China [52]. Wei, Tang, and Zhu (2012) outlined practices of green and low-carbon transformation for the Hangzhou Hongleisi Factory Industrial Heritage Site along the Grand Canal, focusing on key control over land, water, energy, materials, indoor environmental quality, and evaluation without additional costs, demonstrating the positive effects of green conservation and transformation [82]. Florenzano, Courel, and De Domenico (2010) digitally recorded and preserved endangered heritage buildings in oasis cities maintained by water management and canals in the Kashgar region using digital methods [83].

The "#3 Industrial Heritage" cluster includes keywords such as culture and ecological transformation. Industrial heritage sites showcase past industrial processes, raw material extraction, and goods transformation sites. They reflect profound connections between culture and the natural environment, shaping community life and bringing about structural changes to society and the world [3]. For example, Wincott, Ravenscroft, and Gilchrist (2020) highlighted a lack of full understanding of the cultural significance of urban canal waterways as heritage assets for revitalizing former industrial areas by governments, investors, and redevelopment projects [84]. Zhu (2015) proposed recommendations for the protection of characteristic post-industrial urban heritage through ecological transformation, using examples from the Erie Canal and the New York City region [85].

The "#4 Energy-Saving Reconstruction" cluster includes keywords such as historical heritage, green buildings, heritage corridor, and cultural landscape, focusing on the renovation and restoration of buildings themselves. For instance, Somayya and Ramaswamy (2016) presented a case study of buildings along the Amsterdam canal corridor in The Netherlands transformed into smart cities, making significant contributions to Amsterdam's sustainable development through reduced urban pollution, waste of resources, and increased green buildings [86]. Cabau, Hernandez-Lamas, and Woltjer (2022) conducted an in-depth analysis of the evolution of urban architectural landscapes along the Regent's Canal corridor in London [87], emphasizing the formation of a continuous, cohesive foundation through historical multi-purpose values (such as transportation, environment, landscape, and entertainment) layered to transform it into a constantly changing, more diverse linear canal landscape corridor. Gatta and Bitelli (2020) conducted a study on cultural heritage related to artificial waterways in Bologna, Italy, including several silk factories, sewer systems, and ports, using historical geographic information systems and 18th- and 19th-century maps [88]. Additionally, Rong and Wang (2021) proposed a method for interpreting canal heritage from the perspective of historical events using the Hangzhou section of the Grand Canal in China as a case study, revealing the mechanisms by which heritage canals play a decisive role in their associated cultural landscape systems and providing a research basis for the protection and design of heritage canals [36].

Based on the discussion and review of the collected literature databases above, we can see that the hot research topics in canal-related industrial buildings are in line with the concept of sustainable development. Therefore, we summarize them from three angles of sustainable development:

Environmental Sustainability: Research in canal-related industrial buildings focuses on protecting and improving surrounding natural environments and utilizing renewable resources and green technologies to reduce environmental impacts [82]. Researchers not only focus on green transformation of derelict sites and ecosystem conservation but also explore methods to improve energy efficiency and reduce environmental impacts, promoting effective management and utilization of heritage in industrial buildings [41]. This aspect is reflected in the research content of clusters #1 ("Green Space") and #4 ("Energy-saving Reconstruction").

Economic Sustainability: Research in canal-related industrial buildings discusses how to achieve economic benefits while conserving industrial heritage and balancing the relationship between economic growth and heritage conservation [26]. Researchers analyze investment returns, funding issues, and the role of industrial heritage in local economies. By promoting stakeholder participation, better balancing of interests can be achieved to realize economic sustainability [79]. This aspect is reflected in the research content of clusters #0 ("Stakeholders").

Social Sustainability: Research in canal-related industrial buildings focuses on community participation, industrial heritage conservation, cultural continuity, and heritage value preservation during the building protection process. Researchers are committed to maintaining social harmony and promoting community development and progress through heritage conservation and management, ensuring the inheritance of social culture and the overall development of the region [89]. This aspect is reflected in the research content of clusters #2 ("Conservation Areas") and #3 ("Industrial Heritage").

4. Research Trends and Future Directions Analysis

This section integrates the top 10 keywords on industrial buildings related to canals along with the findings from the second and third sections to discuss the current research trends and future directions in the study of industrial buildings related to canals [90], addressing Q3.

4.1. Trends Analysis

Keywords serve as carriers of core information within texts, and their evolution in knowledge graphs reflects the dynamic changes and hot trends in research fields. Particularly frequently and consistently cited keywords often represent cutting-edge research topics [52]. Analyzing such keywords helps identify the most engaging and cited terms in a specific field or research domain, showcasing significant citation growth over a period [91]. Table 8, Keywords with the Strongest Citation Bursts, accurately identifies the top 10 keywords experiencing rapid citation increases within specific timeframes. This table includes two critical points: burst intensity and burst start-stop years. The former represents the strength of the burst, while the latter not only encompasses the duration of the burst but also reveals the shift in research focus [92].

Table 8. Top 10 Keywords with the Strongest Citation Bursts.

Keywords	Strength	Begin	End	1997–2023
water management	0.97	2010	2017	
water history	1.22	2015	2016	
heritage management	0.84	2015	2018	
renovation	1.75	2016	2017	
adaptive reuse	0.92	2017	2021	
urban regeneration	0.89	2018	2023	
design	1.09	2019	2021	
industrial heritage	1.39	2019	2023	
climate change	0.79	2019	2023	
heritage tourism	0.68	2019	2023	

For instance, "water management" maintained the longest duration of prominence, spanning from 2010 to 2017, indicating sustained research interest in water resource management within the past seven years. Initially, industrial buildings related to canals were predominantly focused on the significance of canals in water transportation and canal water management, with less emphasis on the buildings themselves. Research directions included the management of canal water in industrial areas [93]. Following this, "water history" experienced a notable burst within a shorter timeframe, indicating increased scholarly attention towards retrospectively tracing the history of canal water management. Additionally, a burst in the research theme of "heritage management" occurred in 2015, with a longer duration compared to "water history", signifying an expansion of scholarly focus from canal management to heritage management, such as planning and implementing management plans for heritage along canal routes [94].

Moreover, "renovation" exhibited the strongest burst intensity, suggesting a significant growth in research concerning the renovation and restoration of industrial heritage associated with canals within a short timeframe. This reflects the urgent need for the preservation and restoration of industrial heritage related to canals, particularly in the realm of historical and heritage preservation. Through the review of papers, we found that these articles appeared in the Proceedings of the Institution of Civil Engineers—Engineering History and Heritage conference in 2016–2017. During this period, scholars discussed the protection, restoration, and transformation of infrastructure, buildings, and structures, with three papers focusing on canal and industrial building heritage in the ENGLAND, Spain, and Belgium, thus exhibiting high burst intensity [95,96].

The bursts in "adaptive reuse" and "design" indicate a high scholarly focus on adaptive reuse and design from 2017 to 2021, reflecting the urgent need for urban development and revitalization around canal areas. Adaptive reuse refers to the flexible reuse of historical buildings or industrial heritage to meet modern societal needs. This is manifested in appropriately reusing and redesigning industrial buildings based on the actual conditions around canals [72] and intervening in canal-side buildings through various design methods such as ecological design and strategic design [36,71].

Furthermore, the research heat of the four keywords persisted until December 2023, becoming the current hottest research topics. "Urban regeneration" and "industrial heritage" are two noteworthy keywords. The former has garnered scholarly attention since 2018, reflecting the link between canal-related architectural heritage and urban areas. It is no longer limited to the development of individual buildings and communities but plays a crucial role in urban area construction and overall development, thus garnering significant attention in academia [87]. The latter, industrial heritage, is a focal point of research in canal-related architectural studies. Initially established as factories, warehouses, or transportation facilities linked to canals for transport resources, these have now transitioned into industrial heritage, prompting more scholars to discuss this specific type of heritage [97,98].

Research on "climate change" involves two aspects. Firstly, as global climate change intensifies, scholars are delving into the sustainability of industrial buildings. They advocate for the sustainable development and utilization of existing resources such as old canals, barge canals, and other related landscapes to avoid resource waste and environmental pollution, providing a feasible alternative to constructing new buildings [25]. Secondly, rising temperatures leading to sea-level rise have drawn attention to the resilience and adaptability of historical buildings in responding to climate change. For example, rising sea levels may increase the vulnerability of industrial buildings around canals, making protection and restoration work more urgent and critical [33]. These studies highlight academia's current focus on the impact of environmental changes on buildings and heritage.

The final research hotspot is "heritage tourism", also one of the latest hot topics in research from 2019 to 2023. Heritage tourism, as an important form of cultural tourism, has attracted increasing scholarly attention. Scholars are dedicated to exploring how to integrate historical buildings and industrial heritage with tourism to achieve sustainable heritage tourism development, thereby promoting local economic growth and social-

cultural exchanges. In this research field, scholars explore the feasibility of developing heritage along canal banks as tourist resources. This latest research focus not only promotes the effective reuse of resources but also highlights the potential to transform private spaces into more equitable urban public spaces [75,99].

The continuous research on these topics indicates academia's multidimensional focus and exploration of industrial buildings related to canals, providing valuable insights and methods for addressing current social and environmental challenges and for the conservation and management of buildings and heritage.

4.2. Future Research Trends

Following a systematic review of industrial buildings related to canals, we have analyzed the research hotspots on this topic from multiple perspectives. Although existing research angles are diverse and rich, a systematic research framework has yet to be established. Most literature focuses on heritage management and conservation, the revitalization of canal-side landscapes, and canal water resource management. However, there is a lack of systematic research on industrial buildings related to canals, limiting the breadth and depth of research content. Therefore, there is still considerable research space and potential to be explored in this field.

(1) Systematic Identification and Evaluation: Future research can focus on systematically identifying, documenting, assessing, and analyzing industrial buildings along canal routes to explore their conservation and management potential [100]. Such multidimensional categorization aids in deepening the understanding of the characteristics of industrial buildings related to canals and combined with the local economic, historical, and cultural development context, explores the unique value of these buildings, forming a systematic understanding. This, in turn, contributes to raising awareness in this field and ensures effective inheritance and protection of industrial buildings and heritage along canal routes.

(2) Exploration of Architectural Technology and Risk Assessment: In-depth exploration of architectural technical features and risk assessment is crucial for the preservation of industrial buildings [33]. Future research can integrate new restoration techniques, explore the development of more environmentally friendly materials to address evolving environmental challenges, and better showcase the technical value of buildings to ensure the sustainable development of industrial buildings and heritage related to canals [101].

(3) Public Engagement and Social Inclusivity: Furthermore, future research should focus on the role of public engagement in the protection of industrial building heritage related to canals and explore ways to achieve social inclusivity. Communities play a central role in the protection of living heritage, making their direct involvement in interpretation processes essential [102]. Although stakeholder involvement is encouraged, there are still challenges in adjusting heritage protection practices, often resulting in the limited realization of community participation roles [103]. Therefore, future research in the protection of industrial heritage related to canals should consider how to integrate participatory management approaches with heritage protection practices. By promoting public interactive participation, a balance of public interests and social inclusivity can be achieved, ensuring the successful implementation of protection efforts.

(4) Integrated Management for Sustainable Development: Despite scholars not yet providing a systematic summary of industrial buildings related to canals, from the current research hotspots and conservation practices, we can observe a growing focus on industrial heritage conservation based on sustainable development aspects: environmental, economic, and social [104]. For example, the recent attention to "heritage tourism" has driven regional economic development by showcasing the historical, cultural, and technological value of architectural heritage through the development of industrial heritage tourism routes and sites, coupled with landscape environment revitalization. This integrated management approach is expected to bring new research prospects and practical results for the development,

heritage management, and conservation of industrial buildings related to canals, while also making long-term positive contributions to local society and the environment [105].

Global Comparative Studies and Management Systems: Finally, based on categorization and identification of these industrial buildings and industrial heritage types, comparative studies of canal-related industrial buildings and industrial heritage management experiences worldwide can be conducted. By constructing management systems from a global comparative perspective and drawing on international experiences, more scientific and systematic guidance can be provided for the management of industrial buildings and heritage related to canals. Such a research approach helps form a more systematic and global research perspective applicable to a wider range of countries and regions.

5. Conclusions

This study analyzed 96 publications related to industrial buildings along canals from the Web of Science database, aiming to reveal the research prospects and development trends in this field. Based on a thorough analysis of the results, the following conclusions can be drawn:

Firstly, globally, China, England, the United States, Italy, and Spain show high levels of activity in research related to industrial buildings along canals, with a primary focus on the conservation of industrial buildings. Particularly, the University of Bologna in Italy and Southeast University in China lead in terms of publication quantity, highlighting their significant position and research prowess in this field. This reflects the active involvement and professionalism of academic institutions in these countries in the research on industrial buildings related to canals. Among individual researchers, scholars such as Rita Ruiz from Spain and Johan Woltjer from England demonstrate high output and influence in this field. This section addresses research question QR1.

Secondly, through keyword co-occurrence analysis and cluster analysis, we found that renovation, design, and adaptive reuse are the most used methods in the research of industrial buildings related to canals. Additionally, the research combines management methods to manage heritage and canal resources within industrial buildings. Industrial heritage, the Grand Canal, heritage tourism, etc., have become popular research subjects. Stakeholders, green space, conservation areas, industrial heritage, and energy-saving reconstruction form the largest cluster in this field. We found that these research hotspots are closely related to the concept of sustainable development. This section addresses research question QR2.

Overall, despite some academic progress in exploring industrial buildings related to canals, the number of influential publications remains limited. These studies are mainly distributed across 31 countries, with China, England, the United States, and Italy contributing to half of the total research output. This distribution reflects a regional focus in the current research on canal-related industrial buildings, which has not yet garnered widespread global attention. Existing research lacks a systematic framework and is scattered across various research themes, resulting in fragmented and limited findings. This fragmentation restricts a comprehensive understanding of the research content in terms of breadth and depth. Additionally, although the 96 related publications are from high-level international journals, the exclusive use of English-language journals presents certain limitations, as it excludes literature in other languages. Many countries produce a substantial amount of high-quality academic research in their native languages, indicating considerable research space and potential yet to be explored in this field.

Despite these limitations, one of the key objectives of this study is to encourage more scholars to focus on and engage in research on canal-related industrial buildings, thereby promoting current research progress and achieving a more comprehensive understanding. This, in turn, will accelerate the development of urban heritage conservation. Therefore, we suggest that future research could develop in the following directions. Firstly, conducting studies from a local perspective and incorporating data and literature in local languages can complement international research and form a more comprehensive and global research

perspective, especially in countries with a significant number of canal-related industrial heritage sites and research publications. Secondly, phased studies of canal-related industrial buildings can provide a better understanding of their evolution. Additionally, we encourage research institutions worldwide to participate in studies on canal-related industrial buildings. This research should not be limited to existing literature themes such as heritage management, industrial heritage conservation, canal waterfront revitalization, and water resource management. It should also explore the relationship between canals and industrial buildings, including aspects like cultural heritage, sustainable development, urban landscape structure, industrial history, and social change. This approach aims to expedite research progress in this field and promote the sustainable development and preservation of industrial buildings along canals.

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