

Establishing the potential for the application of digital storytelling to support Chinese industrial heritage

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Chinese industrial heritage is the materialized carrier and historical witness of the evolution of urban spatial structure and industrial development. As an inseparable part of cultural heritage, it has rich historical, social, economic, scientific, technological, and aesthetic value. However, industrial heritage as a value is not sufficiently acknowledged in the Chinese society. The factories, their activity, and their historical evolution are often disconnected and isolated from the daily life of the cities, being quite an unknown aspect for most citizens. In addition, due to the acceleration of urbanization, many industrial heritages in cities have disappeared. China has spent two decades promoting sustainable development of its industrial heritage, but there is still a lack of knowledge on how to promote sustainable development of industrial heritage through digital education. Based on these findings the paper discusses our research that promotes sustainable development aspects of industrial heritage, and our subsequent work has particularly focussed on associated landscape recovery. It does so by focussing on the particular highly valued heritage case of the Anshan Steel production site in China, and the environmental consequences of the Dagushan Open mine on the landscape. The paper ends with a critical reflection on how a digital tool can help to shape industrial heritage education, appreciation and involvement, and hence foster sustainable development processes.

Keywords: Chinese industrial heritage, sustainable development, digital storytelling, education, landscape recovery

1 Introduction

An extensive literature search reveals that industrial heritage is being promoted internationally, and has gained more prominence globally. The trends also show that the forms of promoting sustainable development of industrial heritage have been changing. The Dublin Principles (2011) observed that the global process of industrialization observed over the past two centuries constitutes a major stage of human history, making its heritage critical to the Modern World. However, industrial heritage is highly vulnerable and often at risk, and sometimes lost due to lack of awareness, documentation, recognition, or protection and because of changing economic trends, negative perceptions, environmental issues, or its sheer size and complexity (ICOMOS & TICCIH, 2011). By extending the life cycle of existing structures and conserving their embodied energy, preservation of built industrial heritage can contribute to achieving the goals of sustainable development at the local, national, and international levels. The Taipei Declaration for Asian

Industrial Heritage proposes that to ensure sustainable development of the industrial heritage in Asia, the strategies and methods for conservation must be flexible (TICCIH, 2012). The International Council on Monuments and Sites (ICOMOS) proposes in the Heritage and Sustainable Development Goals proposed in 2021 that natural and cultural heritage, tangible and intangible, is critical to fulfilling the United Nations Sustainable Development Goals (SDGs). Among them, SDG 4 aims to “Harness the potential of heritage in supporting quality of and access to education for all” (Labadi et al., 2021) and SDG 9 aims to “Harness heritage for inclusive and sustainable industry and infrastructure, through creativity and innovation” (Labadi et al., 2021).

Some researchers have proposed that using digital technology can help to protect industrial heritage and have suggested that it provides a contemporary way to help conserve and access industrial heritage (Tzima et al., 2020). Applying contemporary digital technologies and the associated theories can support the sustainable

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development of industrial heritage (Zhao, 2014). It can also help in the understanding of cultural heritage more comprehensively, to view it through the lens of industrial heritage (Yu, 2019). Currently, advanced digital technology integrates new information technology into the sustainable development of heritage protection (Yu, 2019). Digital heritage protection activities also enable heritage education and tourism development (Tzima et al., 2020). Benkari (2022) has shown how a digital documentation resource can support education in built heritage. Virtual heritage, as a part of Digital Heritage, represents an extension of social science and information and communication technology, which improves the accessibility and recognition of cultural heritage (Brown et al., 2020) and contributes to the methodological and interpretive reconstruction of relevant academic research (Zhao, 2014). Digital re-interpretation of cultural heritage projects has the potential to be an important part of China's cultural system as illustrated by Li et al. (2013) who showed that the ancient Chinese building design rules can be reinterpreted using contemporary digital parametric tools. Increasing public understanding and protection of cultural heritage can revitalize cultural heritage (Xu et al., 2020) and enrich China's public awareness, appreciation, and understanding (Guo et al., 2020).

We can conclude, therefore, that digital heritage can offer promising ways to educate the public and promote the sustainable development of China's industrial heritage more effectively. It allows for interconnections across different knowledge domains and scales. In our case the heritage activities involve the landscape remediation of the Dagushan mine, one of the largest in the world.

2 Material and methods

This study described in this paper employs a bibliometric approach to investigate China's promotion of sustainable industrial heritage development over the past 20 years. Utilizing the China National Knowledge Infrastructure (CNKI) database and CiteSpace software (Version 5.6.R5), we analyzed publications and trends in this field to gauge its significance and level of academic concern. Keywords and author data were processed to generate knowledge graphs that reveal research trends and gaps. Our inductive analysis further elaborated on the research background and potential drivers for sustainable development in China's industrial heritage sector. The search, conducted on August 26, 2022, yielded a total of 565 related works, including 189 journal papers and 376 dissertations dating back to as early as 2002 and 2004, from which 559 were selected for this study after excluding unrelated literature. Based on 559 literature samples, this study used Excel as a clue to conduct statistics and obtained the distribution map of literature on the sustainable development of industrial heritage in China, as shown in Figure 1.

2.1 Research trends and directions

This section firstly looks at an overall trend analysis and then presents a more focussed analysis relating to digital technology application in an educational setting.

2.1.1 Overall Trend Analysis

From the overall identified trends, it can be observed that the amount of literature shows a trend of gradual increase. Taking the number of issued each year as the reference point, the research on the sustainable development

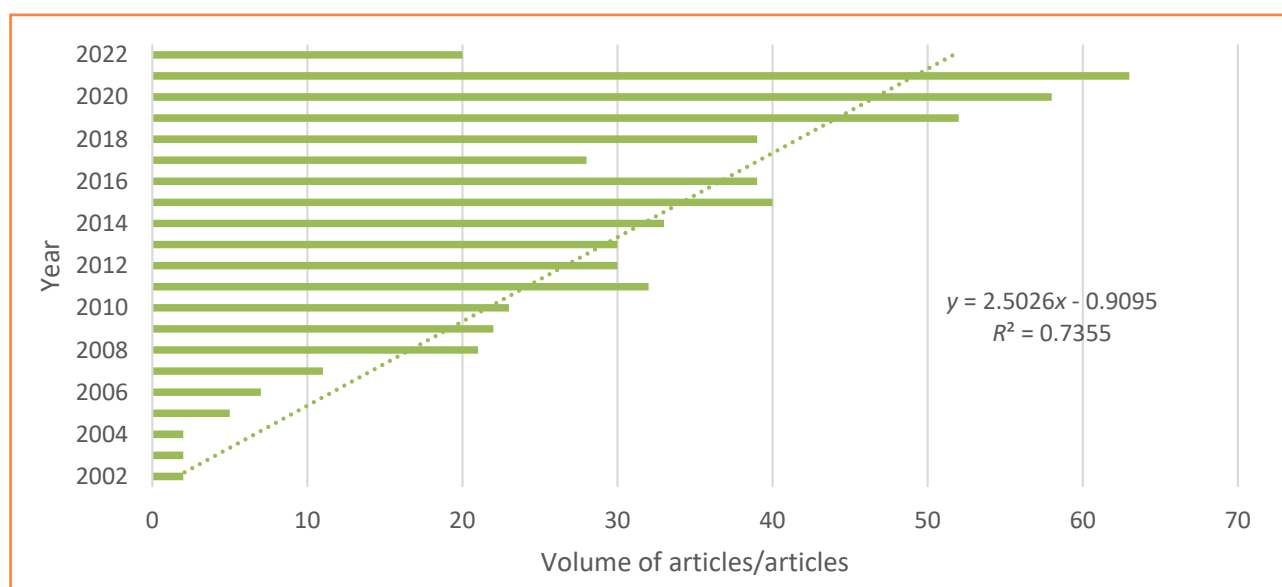


Figure 1 Annual distribution trend of literature quantity on sustainable development of industrial heritage from 2002 to 2022

of China's industrial heritage can be roughly divided into three phases: In the first stage (before 2002), there was no substantive content related to promoting the sustainable development of the industrial heritage. It seems that experts and scholars paid little attention to this field of research prior to 2002. From 2002 to 2006, the literature volume increased slowly, which was the initial stage of sustainable research on China's industrial heritage, and most of them were analyses on how to preserve industrial culture through the transformation and utilization of industrial buildings (Palombini, 2017). In the second stage in the period 2006 to 2016, China put forward the 'Charter of Wuxi' (2006) that focussed on the protection of industrial heritage in the period of rapid economic development and stress the importance of protecting China's industrial heritage. Thus, two years later, the first significant research output period appeared in the study of China's industrial heritage. In 2012, in the research of the 'Taipei Declaration on Asian Industrial Heritage', scholars discussed how to set up industrial heritage protection mechanism with Asian characteristics. This would have a focus according to the Asian industrial heritage history and status quo under the framework of international heritage protection is an important task faced by all countries in Asia. Especially in countries like China which is facing industrial transformation with a high-level development of urbanization, pathways for industrial heritage protection with local characteristics are of great significance for a future sustainable heritage engagement.

Thus, the volume of relevant literature reached a new peak in 2015 and then began to slow down. In the third period (2016–2022), and the number of articles decreased

in 2017 to only 28 outputs. But continued to increase after 2018, and reached a peak in 2021, with 63 different outputs in a year. In 2021, ICOMOS formally promulgated the heritage and the sustainable development goals document: "policy guidance for heritage and development actors", in which heritage – natural and cultural, tangible, and intangible – is fundamental to addressing the United Nations (UN) Sustainable Development Goals (SDGs) (Labadi et al., 2021). The 2030 Agenda also pointed out that the value of heritage should be used to accelerate the sustainable development goals. This means not using heritage only to maintain and deliver heritage values but also to harness and enhance heritage resources to support the goal of sustaining life on earth (Labadi et al., 2021). Through the analysis of the literature trends noted above, it is evident that promoting the sustainable development of industrial heritage is a key research field that both China and the world are concerned about at present.

2.1.2 Trend analysis of education and digital technology

In 2020, the World Heritage Institute of Training and Research for the Asia and the Pacific Region (WHITRAP) proposed that the value of industrial heritage history should be deeply explored given the value of combining technological innovation and cultural education (Benkari, 2022). Meanwhile, SDG 4-sub goals encourages stakeholders to "utilize heritage as a source of creativity and innovation to shrink achievement by making learning meaningful and relatable to cultural contexts." TICCIH (2012) and SDG 9 sub-goals identify the need to "promote the integration of creative, innovative solutions in heritage conservation and management

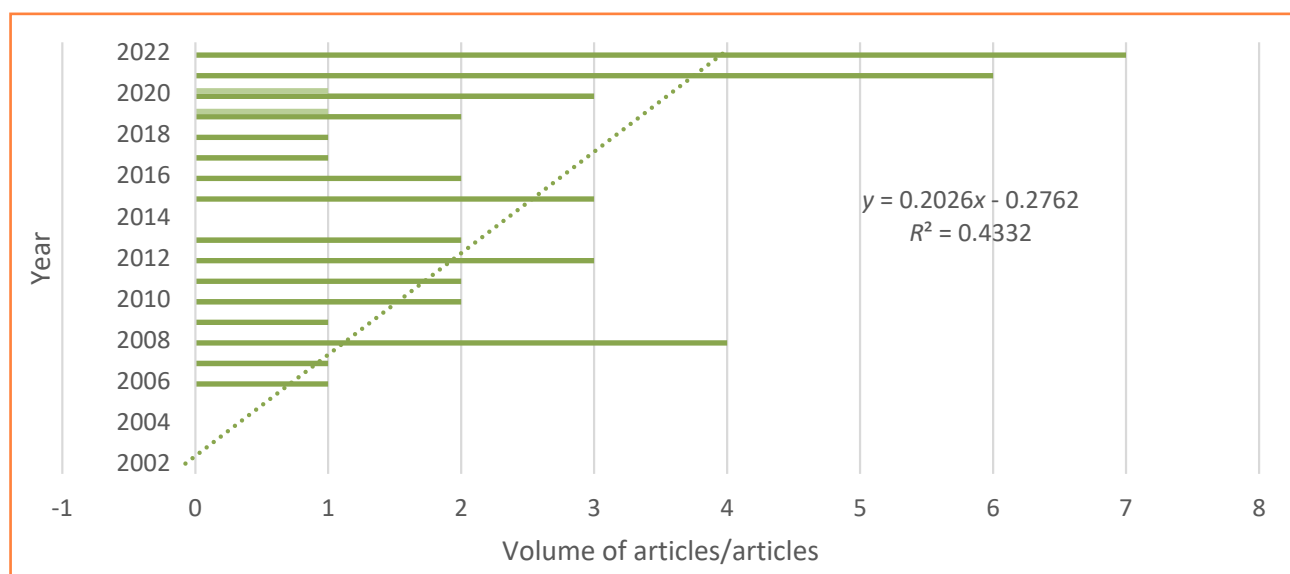


Figure 2 Trend analysis on education and digital technology for sustainable development of industrial heritage

processes, along the principles of respecting the integrity of heritage, safeguarding continuity and memory, and ensuring quality in contemporary design” (Labadi et al., 2021). This illustrates that promoting the development of heritage through education and innovative methods has become an important development goal.

In our research, we searched for “industrial heritage”, “sustainable development”, “education” and “digital technology”, and found a total of 36 papers on promoting sustainable development through education, of which four papers were published in 2008, reaching a peak during that period. After more than ten years of fluctuations, the overall trend slowly rose until 2021 with the highest number of 7 papers. Furthermore, there are only two papers on promoting the sustainable development of industrial heritage through digital technology in 2019 and 2020. Therefore, at present, promoting the sustainable development of industrial heritage through these two forms of education and communication has not been the research emphasis of Chinese heritage experts and scholars (Figure 2).

2.2 Research and trend analysis based on keywords

In this section, we explore the current efforts made by Chinese experts and scholars in promoting the sustainable development of industrial heritage. The investigation uses the analysis of keywords, intensifiers, time zones, and clusters, to analyze the existing deficiencies in research, and to suggest a focus for future research.

2.2.1 Parameter setting

In CiteSpace, the keywords were taken as the network node. The period was set as 2000–2022, the time partition value was 1, and the threshold was Top 50 per slice. In addition, the keyword co-occurrence knowledge graph was obtained by using Pathfinder and pruning sliced networks as well as merged networks. It is noteworthy that through reading a large number of outputs on the sustainable development of China’s industrial heritage, it can be found that most of the articles in this field refer to the same research object, but use different terms to define it. Therefore, our study combines relevant concepts and finally determines four essential categories: protection and reuse, urban renewal, landscape design, and industrial tourism. To get more information, the threshold was set as 0, and the keywords with a frequency less than 2 times were removed (Figure 3). Ultimately, 380 nodes and 542 inter-node connections were generated, with a network density of 0.0075. The overall structure is relatively compact. The research focus on the sustainable development of the industrial heritage is therefore relatively concentrated, and notably, landscape renovation and regeneration have had relatively little attention. The size of the node radius denotes the keywords’ word frequency, and ‘industrial heritage’ is the biggest node, which may reflect the search term. The other significant nodes are urban renewal, reuse, reconstruction, protection, and tourism development.

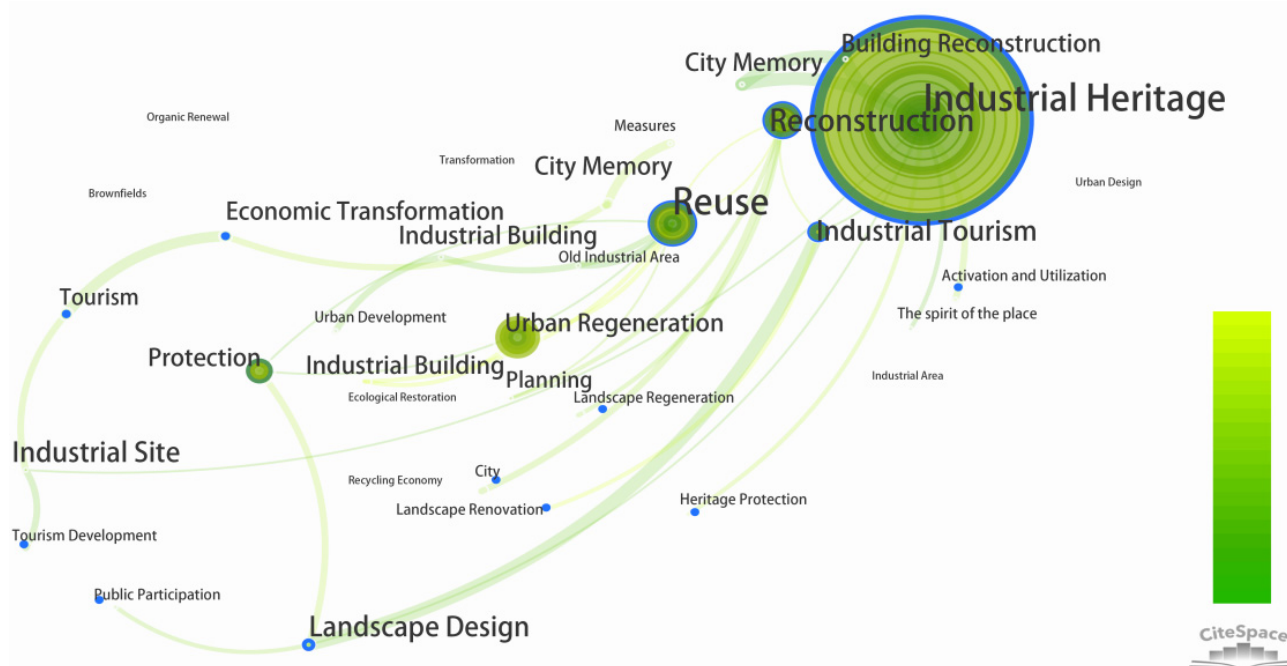


Figure 3 Keyword co-occurrence network on sustainable development of industrial heritage in China from 2002 to 2022

2.2.2 The centrality of research on keywords

The centrality of nodes can reveal the importance of keywords (Zhong et al., 2020). Specifically, the nodes with high centrality are the 'pivotal nodes' in the network. Industrial heritage, reuse, and urban renewal can be seen to be the high and medium centrality nodes in the common word network of research on sustainable development of industrial heritage in China. This represents the gap of scholarly attention in this field. Table 1 lists the top ten keywords and their frequencies, which are mainly focused on two categories: One is the themes related to promoting the urban development and reuse of industrial heritage, with urban renewal, reuse, industrial heritage preservation, and landscape design as the core. The other is the themes represented by renewal strategies and urban 'dual renovation' and ecological restoration. Dual Renovation of an area involves a combination of new construction, whilst preserving heritage assets where appropriate. In terms of the time dimension, the first category of research gap appeared earlier, as early as 2003, while the second category of research gap appeared later, after 2020. In total, this appears to define the current research gap relating to the attention given by experts and scholars as well as in research social networks.

2.2.3 Keyword emergence analysis

Keyword emergence refers to the sudden addition of keywords in related fields in a certain period, and a keyword co-occurrence analysis originates from the coupling analysis in bibliometric analysis. A comprehensive keyword emergence analysis and keyword co-occurrence analysis can be conducted to identify both a research gap, and the evolution of the gap along with associated ideas such as technologies, theories, and methods that have prominent driving effects in related fields (Hua & Wu, 2021). CiteSpace software together with the Burst

Detection Algorithm (Sun & Mao, 2018) are used to cluster technical terms with rapid changes in frequency from the title, keywords, abstracts, and other document identifiers of the document.

For this paper, we analyzed 565 Chinese documents from the CNKI database for keyword emergence and merged synonymous keyword nodes, and set the minimum time as 2 years, the state transition value as 1, and the state difference ratio as 2. The produced the 14 keywords with the highest emergence intensity. The temporal distribution of the top 14 keywords (from 2004 to 2022) is shown in Table 2, which indicates the distribution of the emergence time and duration of these emergent keywords. According to the results of the emergence, the keywords with emergent intensity greater than 2 are "Transform" (3.98), "Tourism" (2.71), "City" (2.33), "Ecological Restoration" (2.3), and "Tourism Development" (2.15). The keywords that appear for more than 5 years are "Renew" (2006 to 2011).

These keyword trends play a crucial role in the study of the sustainable development of industrial heritage. From a temporal perspective, the keywords that emerged before 2015 focus more on urban renewal, tourism development, economic transformation, and renovation of industrial buildings to promote the development of industrial heritage, such as "Urban Design", "Tourism Development", and "Economic Transformation". The keywords emerging after 2015, particularly from 2018 to 2022, reflect that new strategies are gradually introduced to promote the sustainable development of industrial heritage in this period. This is reflected in terms such as ecological restoration, urban repair, improvement of habitat, and transformation of urban development (e.g., "Ecological Restoration", "Design Strategy" and "Urban Dual Renovation"). Experts and scholars tend to believe that the rapid transformation of industrial

Table 1 Main keywords in the literature on sustainable development of industrial heritage in China, 2002–2022

Serial number	Count	Centrality	Year	Keywords
1	117	0.6	2004	industrial heritage
2	28	0.16	2007	urban renewal
3	32	0.12	2007	reuse
4	19	0.08	2008	protection
5	5	0.06	2009	urban development
6	25	0.05	2007	transform
7	4	0.05	2007	landscape
8	3	0.05	2021	update strategy
9	3	0.05	2020	urban dual renovation
10	15	0.03	2008	landscape design

Table 2 Keyword prominence in the literature on the sustainable development of China's industrial heritage 2002–2022

Keywords	Year	Strength	Begin	End	2002–2022
Urban design	2002	1.74	2003	2007	
Old industrial area	2002	1.71	2005	2007	
Tourism development	2002	2.15	2006	2009	
Renew	2002	1.73	2006	2011	
Spirit of place	2002	1.59	2007	2008	
Tourism	2002	2.71	2012	2015	
Economic transformation	2002	1.94	2012	2016	
Transform	2002	3.98	2013	2014	
City	2002	2.33	2013	2015	
Ecological restoration	2002	2.3	2018	2020	
Industrial heritage	2002	1.79	2019	2022	
Design strategy	2002	1.75	2019	2022	
Urban renewal	2002	1.69	2019	2020	
Urban two-layer restoration	2002	1.55	2020	2022	

cities, the rapid transformation of industrial buildings, and the renovation of industrial buildings have been the most important factors. Therefore, most conclude that there is an urgent need to gradually transform from uncoordinated growth to well-managed development, to build some modern cities that are harmonious, livable, dynamic, and distinctive. Part of being distinctive is to retain aspects of important heritage, including industrial heritage.

2.2.4 Gap time zone map analysis

The keyword research gap time zone map shows the distribution and changes of keywords in a topic or field in different periods. This helps us to identify the gap topics and their evolution process of research in the field of sustainable development of Chinese industrial heritage from the dimension of time. Looking at the time zone diagram of the keywords in the research literature in this field over the past two decades (Figure 4), we can find that industrial heritage conservation and reuse are the persistent gap topics in China's research on the promotion of sustainable development of industrial heritage. Furthermore, the evolution process of China's research on sustainable development of industrial heritage can also be summarized as the change process of industrial heritage reuse, which has broadly gone through three stages: The period of enthusiasm for transforming and reusing industrial heritage → the period of promoting economic development → the period of adjusting new protection policies and entering the period of "urban two-layer restoration" of ecological restoration and

urban repair. Therefore, the whole phase is a process with a range of speeds from fast to slow.

TICCH is the world organization representing industrial heritage acts as special adviser to ICOMOS on industrial heritage. In the first phase (2002–2009), TICCH has since 2003, formally proposed the value of industrial heritage and the importance of preserving it. In 2006, the Wuxi Charter was put forward, making the preservation and reuse of industrial heritage an important issue that has gradually become a focus of attention during this period. According to most experts and scholars, the top priority in this period is how to make these abandoned industrial heritage assets play their role in the huge urban space, and how to use industrial heritage reasonably. This is so that it can properly protect industrial heritage and contribute to urban regeneration (Wuxi Proposal, 2006).

In the second phase (2010–2017), to develop the economy, raise the income level, maintain the economy, and promote the development of society, many industrial heritage sites finally moved towards the development phase of "black" to "green" (Zhao & Li, 2022). Many industrial heritage sites have been transformed into parks for people to visit, thus exploring tourism development and proposing feasible strategies that are in line with the transformation of industrial heritage and sustainable economic development. In the third phase (2018–2022), "urban two-layer restoration" has become a research gap in this period. In 2015, the term "urban two-layer restoration" was officially introduced by the Ministry of Housing and Construction

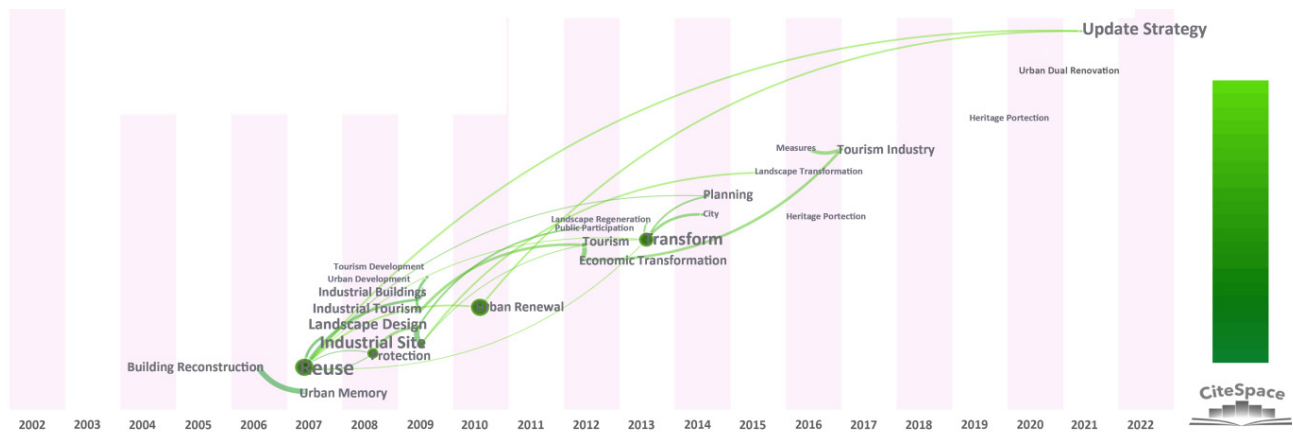


Figure 4 Visual mapping of emergent keywords presented in the way of time and region from 2002 to 2022

of China (Yu, 2022). In March 2017, the Guidance on Strengthening Ecological Restoration of Cities and Urban Repair was published, which proposed that urban development is no longer about big demolition and new construction, but about planned planning of urban stock (Tu et al., 2022). The “two-layer restoration” will be the main guiding principle of urban development and construction, which will focus on the treatment of urban diseases, promote ecological construction, and improve urban functions. In the period since 2020 experts and scholars have gradually used the concept of “urban two-layer restoration” as a guide to drive the sustainable development of industrial heritage. Meeting people’s increasing demand for a better life, preserving the culture of the site, improving the service function of the site, and providing a livable living environment has become the main purpose of an increasing body of scholarly research.

2.2.5 Cluster analysis

Keyword clustering is an interconnected network cluster formed by keywords that refer to similar research topics in the research field, and the connotation of each cluster is identified by the title words that are frequently used in an article. In CiteSpace, nodes of the same cluster were covered with a convex shell or only showed boundary lines, and clusters were numbered from 0. Specifically, cluster #0 is the largest cluster, and cluster #1 is the second largest, in descending order (Liu et al., 2018).

In our study, the keyword network was clustered by the Log-Likelihood Rate algorithm (LLR), and the name of the feature word with the highest value of the LLR operator in the class was used as the cluster name (see the clustering results in Figure 5). The effect of cluster clustering is usually measured according to two indicators, the clustering modularity index (Q value) and the cluster profile index (S value). In general, the larger the Q value and the S value,

the better the clustering effect of the network. When the Q value exceeds 0.3, network clustering is generally considered to be effective. When the S value is greater than 0.5, clustering is often considered a reasonable (Yao, 2014). The values of $Q = 0.8533$ and $S = 0.983$ in our study indicate that the clustering profile is credible.

A total of 95 clusters were obtained in this study, and the first 10 large clusters (Figure 5) were extracted for analysis, and the top ten clusters were further summarized, which were divided into four categories: urban renewal, protection and reuse, landscape design, and industrial heritage tourism development.

Urban renewal and protection reuse: this category encompasses clusters #0, #3, #6, and #9, highlighting feature words such as “urban renewal,” “sustainable development,” and “industrial heritage protection.” Zhu (2019) explored the relationship between urban industrial culture and heritage. Zhang Wenzhuo emphasized the need for transforming industrial sites into creative hubs (Wang, 2011). Zhao (2019) used Cite Space to summarize the trends in urban renewal, including micro-transformations and adaptive reuse.

Landscape design: covering clusters #1, #2, #7, and #8, this theme includes feature words like “ecological design,” “landscape transformation,” and “regional characteristics.” Chen Chuan (2015) discussed methods for transforming industrial landscapes to benefit residents, while Wu Hongwei (2021) proposed design strategies based on principles of authenticity and ecological priority.

Tourism development: this theme comprises clusters #4, #5, and #9 and centers on “tourism development,” “resource-exhausted city,” and “market positioning.” Wang (2011) argued for the development of industrial heritage tourism, and Liu Xuezheng examined how industrial tourism can revive resource-depleted cities (Cao, 2022). The literature referenced herein shows that

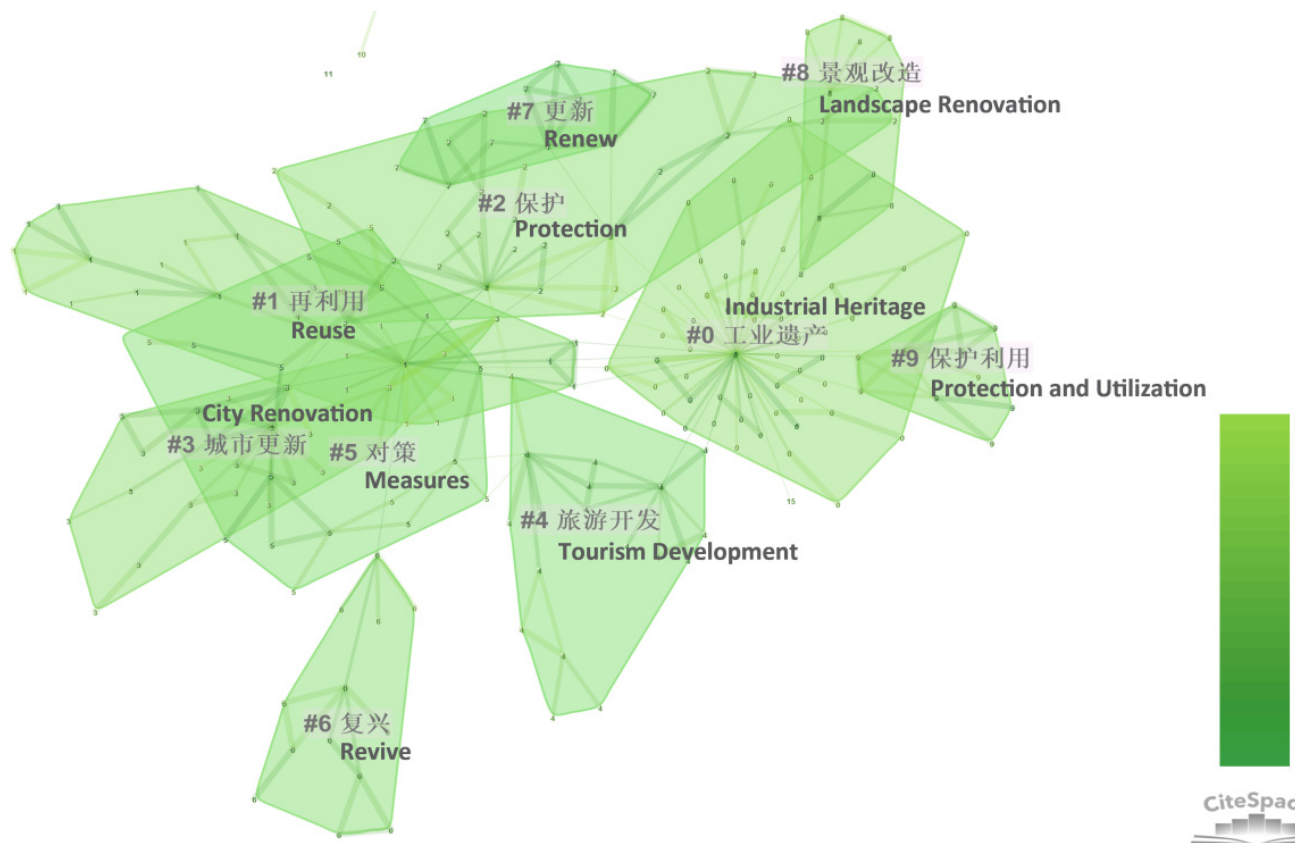


Figure 5 A visual map of keyword clustering in the sustainable development literature of Chinese industrial heritage from 2002 to 2022

these themes are crucial in the current discourse on industrial heritage and sustainable development.

3 Results and discussion

From the above analysis, it can be easily seen that China has been promoting sustainable development of industrial heritage for 20 years, but the focus has been on three major areas: Urban Renewal and Conservation Reuse, Landscape Design, and Tourism Development. What is lacking is that there is no research undertaken that focuses on novel ways of transmitting knowledge of industrial heritage through digital storytelling and promoting a sustainable industrial heritage and thus educating the public.

3.1 Reflections on the experience

With the rapid development of China, industrial restructuring, and economic transformation, a large amount of industrial heritage has come into the focus of social attention and become an important issue in urban development. At the same time, industrial heritage is a treasure trove of resources storing the city's history, culture, and collective memory. However, due to the lack of awareness and inappropriate methods

of conservation and reuse, a lot of industrial heritage has been transformed, updated, and transformed, causing many industrial heritages to disappear or semi-disappear. Moreover, the "production memory" carried by it has become diluted, fragmented, and blurred due to the lack of context. Especially for young people and children, the "collective memory" and "production memory" have gradually become niche and unknown, and eventually turned into the "collective amnesia" of the whole society. Therefore, the way to promote industrial heritage should be changed to let more people know about China's industrial heritage, their development history, and learn about the production process, to educate the public more conveniently and interestingly. Moreover, our subsequent research has found that using digital storytelling to restore, recreate and reproduce industrial heritage and memories in an online realm is an effective means to preserve the past, guard memory and transmit knowledge in a participatory and un-mediated way that is part of a larger heritage, architectural and urban ecosystem (Vrettakis et al., 2019).

3.2 The way forward

3.2.1 Storytelling approach

First of all, a linear story-based mobile application, the so-called 'linear narrative', is a top-down narrative process that guides the user indirectly through a story-centered approach (Spierling et al., 2002). Brown et al. (2020) proposed that if a memory process uses a story as a vehicle, this can be the instigator of a creative and richer thought process. The readers can immerse themselves in the world of the story they are exploring through the reading experience. These characters may be in a fictional urban setting or a real setting from memory. Subsequently, our study uses a linear narrative to tell the story of Chinese industrial heritage in a more coherent way to guide users to learn and understand the history and the future value.

3.2.2 Presentation of the story

Linear story representation can be created using the stop motion technique, a simple and well-known technique that has been used for more than a hundred years (Tzima et al., 2020). Stop-motion animation is an effective way to show linear narrative. Most importantly, stop-motion animation is interesting and lively style, which can help all kinds of people and ages to understand the content, in our case, the site-specific industrial heritage and associated landscape remediation.

3.2.3 Prototype of digital storytelling high-fidelity

With an intuitive, simple, and cost-effective, web-based solution we can collaborate with stakeholders of different levels of expertise and jointly evaluate them on-site (Aydin & Schnabel, 2016). The high-fidelity prototype can fully display the functional modules, visual elements, human-computer interaction forms, and effects. At the same time, the high-fidelity prototype allows the entire design process of the application to be experienced. Finally, through user testing, we analyze the data gained to validate our hypothesis.

Lastly, the emergence of digital storytelling will be not only the only way to preserve and develop China's industrial heritage, and the construction of meaning (Rushton & Schnabel, 2022) but it is a novel powerful resource to facilitate participatory and un-mediated engagements that respond to the broader ecosystem of interconnectivity in livability focused cultural realm. It is hoped that our research serves as the departing point to give rise to the sustainable development of industrial heritage in terms of awareness, methodology and education.

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