Perception of sponge city for achieving circularity goal and hedge against climate change: a study on Weibo

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Abstract

Purpose – Global climate change speeds up ice melting and increases flooding incidents. China launched a sponge city policy as a holistic nature-based solution combined with urban planning and development to address flooding due to climate change. Using Weibo analytics, this paper aims to study public perceptions of sponge city.

Design/methodology/approach – This study collected 53,586 sponge city contents from Sina Weibo via Python. Various artificial intelligence tools, such as CX Data Science of Simply Sentiment, KH Coder and Tableau, were applied in the study.

Findings – 76.8% of public opinion on sponge city were positive, confirming its positive contribution to flooding management and city branding. 17 out of 31 pilot sponge cities recorded the largest number of

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sponge cities related posts. Other cities with more Weibo posts suffered from rainwater and flooding hazards, such as Xi'an and Zhengzhou.

Originality/value – To the best of the authors' knowledge, this study is the first to explore the public perception of sponge city in Sina Weibo.

Keywords Climate change, Water issues, Sponge city, Social media, Public perceptions

Paper type Research paper

1. Introduction

Flooding has become a global natural hazard when climate change speeds up the ice melting in the Antarctic ice sheet (Stokes *et al.*, 2022). It has become a global concern in recent years (Tian *et al.*, 2023). It adversely impacts humans and societies when urbanisation intensifies (Cheng *et al.*, 2022). According to the World Meteorological Organization (WMO) (2022), more than 11,000 water-, weather- and climate-related disasters have been reported, resulting in more than two million deaths, an average of 115 deaths per day and $3.64tn economic losses over the past 50 years.

According to Zha *et al.* (2021), Zhao *et al.* (2019) and Nguyen *et al.* (2019), countries worldwide have implemented various water control measures since the 19th century. France incorporated the urban drainage system into the construction plan in 1852. The UK began to build underground drainage system in 1859. Germany emphasised "zero increase in drainage" in 1990s. Japan promoted the "rainwater retention and infiltration plan" in 1920, and Tokyo built the world's most advanced sewer drainage system since 1992. The USA has constructed large-scale drainage systems since 1972, proposed the low-impact development model in urban construction and enforced "in-situ flood storage". The USA was the first country to research stormwater regulation and storage. Besides, Australia has prevented and controlled urban waterlogging since 1975. In Bangladesh, floating garden generates economic, social and ecological benefits in low-lying areas (Abdullah Al Pavel *et al.*, 2014).

In recent years, China has launched a new national initiative called "sponge city" which enables cities to absorb and save rainwater like sponges (Zhang *et al.*, 2019; Guan *et al.*, 2021) to improve urban resilience. It is a low-impact development rainwater system (Guan *et al.*, 2021) that aims to solve the problem of water storage and waterlogging, reduce water pollution, improve water quality and enhance water ecology (Gu and Cui, 2017; Ji and Bai, 2021).

Although sponge city has become increasingly prominent (Lin *et al.*, 2019), it requires highly collaborative and innovative work (Gu and Cui, 2017). Sponge city construction has many problems and controversies due to high construction costs, a lack of technical guideline, high management costs and low management efficiency (Zhang *et al.*, 2019). Fu *et al.* (2022) doubted whether sponge cities provided appropriate solutions to China's growing urban flooding problems: it needs all stakeholders' joint efforts (Gu and Cui, 2017). On the other hand, sponge city provides solutions to water hazards and disasters and improves the urban environment and human well-being. Thus, thriving sponge cities enhance urban resilience and city branding (Thadani *et al.*, 2020). Likewise, online social media content reflects the public's perception, content about sponge city affects a city's brand image (Thadani *et al.*, 2020).

Thadani *et al.* (2020) analysed the current application of China's online social media in city marketing and branding based on the sponge city plan. Besides city branding, sponge city construction requires active participation and public support. As Sina Weibo is China's leading social media, public opinion mining could be useful to know more about stakeholders' perception on sponge city. Yet, research on the public perception of sponge city on Sina Weibo is scarce. To fill the research gap, the study analysed data by Python and artificial intelligence (AI) tools to study the public's foci, locations, content and sentiment on

Sina Weibo. It provides policymakers with insights regarding the public's main concerns about sponge city.

This paper puts forward the following research questions:

RQ1. What are the public's concerns about sponge cities?

RQ2. Are the sponge cities posts optimistics?

RQ3. Has the sponge city concept been efficiently communicated among the public?

The study's objectives are as follows:

- to visualise and analyse the popular topics and content about sponge city on Sina Weibo;
- to study the sentiment of Weibo's sponge city posts and the possibility of sponge city to enhance city branding; and
- to explore the beneficial strategies for government and enterprise about sponge cities based on the public's perception.

This paper offers valuable information to monitor sponge city development policies to address water scarcity and climate change challenges. Besides, it proposes that government departments to address public opinions in social media, which helps them formulate policies, spreads the sponge city concept and encourages residents to participate.

This article consists of six sections. The literature review is described in Section 2. The research method is in Section 3; Section 4 describes the data analysis; Section 5 describes the results and discussion; and Section 6 gives the conclusion. With big data and social media analytics, this research offers a new perspective on investigating the public perception of sponge cities, providing insight to the government to improve sponge city communication and brand management.

2. Literature review

2.1 Global water strategies

Water problems brought by climate change is one of the global challenges in pursuing sustainable urban development (Ma and Jiang, 2022). Countries use different measures to control flooding:

- sustainable urban drainage systems in the UK (Ma and Jiang, 2022) minimise surface water runoff and flooding risk by mimicking natural water systems such as ponds, wetlands, depressions and basins;
- water-sensitive urban design in Australia (Ma and Jiang, 2022) installs green stormwater infrastructure that uses facilities to reduce the impact of urbanisation and enhance cities' comfort, ecosystem and livability; and
- the Active, Beautiful and Clean Plan in Singapore aims to create beautiful and clean streams, rivers and lakes and provide postcard-like community spaces by integrating drains, canals and reservoirs holistically with their surroundings (Tan *et al.*, 2019; Nguyen *et al.*, 2019).

2.2 Sponge city in China

According to the Ministry of Water Resources and the Ministry of Emergency Management of the People's Republic of China (PRC), flooding in China caused about 1,974 people die or

missing annually on average, and more than 60,000 deaths from 1991 to 2021. It caused an average annual direct economic loss of about 163.2 billion CNY and approximately ¥5.05tn (Ministry of Emergency Management of the PRC, 2022). China wishes to transform 80% of built-up areas to sponge cities by 2030.

China's strategic plan at the national level regarding sponge city includes notices, commitments, systematic planning and implementation. Table 1 shows China's sponge city policies since 2014. In 2015, the Ministry of Finance, the Ministry of Housing and Urban-Rural Development and the Ministry of Water Resource of the PRC jointly issued a document to implement the pilot sponge city and explore the best approach that fits China's conditions. Sponge city has received significant attention and a positive response from the local government. In June 2015, the national government conducted sponge city construction performance evaluation and assessment from six aspects:

(1) water ecology;
(2) water environment;
(3) water resources;
(4) water security;
(5) system construction and implementation; and
(6) visibility (Ministry of Housing and Urban-Rural Development of the PRC, 2015).

In 2015 and 2016, pilot sponge city construction took place in 30 cities in China. According to the Ministry of Housing and Urban-Rural Development of the PRC (2017), China's Urban Municipal Infrastructure Construction "13th Five-Year Plan" proposed that over 20% of urban built-up areas must meet the sponge cities' requirements in 2020 and reach 80% in 2030. In February 2019, sponge city was required to protect the natural ecological pattern. The goals were achieved through retention, infiltration, storage, purification, emission and utilisation (Ministry of Housing and Urban-Rural Development of the PRC, 2019). In 2022, sponge cities construction was included in the "14th Five-Year Plan", it included 25 sample cities and the central finance provided subsidies to the pilot cities (Ministry of Finance of the PRC, 2022).

The PRC government and municipal departments attach great importance to sponge city and consider the public's safety and health first. Sponge city policy purifies and beautifies the cities, improves city quality and enhances public people's happiness (WU and QIN, 2019). Table 1 shows the strategic plans in China from 2013 to 2022.

2.3 Sponge city for climate change in China

The Chinese government attached great importance to adaptation to climate change and has introduced relevant strategies and policies. Owing to climate change, rapid urbanisation, changes in land use and rapid socioeconomic development, surface water inundation was the most severe water-related problem in many large cities in China (Chan *et al.*, 2018). It included extraordinary precipitation in Beijing, Jinan, Chongqing, Zhengzhou, etc. In sponge city research, scholars have studied the future adaptive countermeasures of different cities regarding climate change, especially urban flooding risk resilience. The analysis included Shanghai (Tong *et al.*, 2022), Beijing, Tianjin, Shenzhen (Shao *et al.*, 2021), Guangzhou, Chongqing, Zhengzhou (Tong *et al.*, 2022), Jinan (Cheng *et al.*, 2022), Xi'an (Luo *et al.*, 2022), Nanjing (Liu *et al.*, 2021), Wuhan (Dai *et al.*, 2018) and Xiamen (Shao *et al.*, 2018).

Ma and Jiang (2022) studied China's sponge city's ecosystem-based adaptation to address urbanisation and climate issues. Applying the Geodesign framework as an integrated

Time	Plan and strategy
12 July 2013	Ministry of Housing and Urban-Rural Development of the PRC (MOHURD) issued the Outline of Comprehensive Planning for Urban Drainage (Rainwater) and Waterlogging. All cities must formulate comprehensive urban drainage (rainwater) and waterlogging prevention plans per local conditions
12 December 2013	In the Central Work Conference on Urbanization, Xi Jinping suggested prioritising the use of natural water drainage methods and building a "sponge city" with natural accumulation, infiltration and natural purification
14 February 2014	MOHURD Urban Construction Department developed a new concept of building a sponge city and compiled the "National Urban Drainage and Waterlogging Prevention Facilities Construction Plan"
14 June 2014	The General Office of the State Council of the PRC issued guiding opinions on strengthening the construction and management of urban underground pipelines. It aimed to promote the renovation and construction of rainwater and sewage diversion pipe networks
21 August 2014	MOHURD and National Development and Reform Commission (NDRC) issued a notice to strengthen urban water conservation further and control the use of water for ecological landscapes
17 September 2014	State Council of the PRC replied the National Plan for Addressing Climate Change (2014–2020)
22 October 2014	MOHURD issued the notice on Printing and Distributing Technical Guidelines for sponge city Construction – Construction of Rainwater System for Low-impact Development (Trial)
31 December 2014	Ministry of Finance of the PRC (MOF), MOHURD and Ministry of Water Resource of the PRC(MWR) issued the Notice on Carrying out Central Financial Support for sponge city Construction Pilot Work
2 April 2015	The 2015 List of sponge city Construction Pilot Cities were announced
10 July 2015	MOHURD issued the "Notice on Printing and Distributing sponge city Construction Performance Evaluation and Assessment Methods (Trial)"
20 October 2015	The General Office of the State Council of the PRC issued the Guidance on Promoting sponge city Construction
10 December 2015	MOHURD China Development Bank (CDB) issued the Notice on Promoting Development Finance Supporting sponge city Construction
30 December 2015	MOHURD Agricultural Development Bank of China (ADBC) issued a Notice on Promoting Policy-Based Financial Support for sponge city Construction
5 February 2016	MOHURD Notice on Printing and Distributing the National Building Standard Design System for Urban Comprehensive Pipe Gallery, and sponge city Construction was issued
2 May 2016	Notice on carrying out the Central Financial Support Sponge City Construction Pilot Work in 2016 Application Guidelines for sponge city Construction Pilot Cities was announced in 2016
25 May 2017	The 13th Five-Year Plan for National Urban Municipal Infrastructure Construction proposed accelerating the construction of sponge cities
30 November 2018	MOHURD Notice on Printing and Distributing Investment Estimation Indicators for sponge city Construction Projects
13 February 2019	MOHURD Announcement on Publishing the National Standard "Technical Standards for Operation, Maintenance and Safety of Urban Underground Pipe Gallery"
10 April 2019	MOHURD Announcement on Issuing the National Standard "Evaluation Standards for sponge city Construction"

(*continued*)

Table 1.
Sponge city strategic plans in China from 2013 to 2022

Time	Plan and strategy
1 December 2020	General Office of MOHURD Notice on the Public Solicitation of National Standards "Construction Acceptance and Operation and Maintenance Standards for Sponge City Construction Projects (Draft for Comments)" and "Special Planning and Design Standards for sponge city Construction (Draft for Comments)"
29 December 2021	General Office of MOHURD, General Office of NDRC, General Office of MWR, General Office of Ministry of Industry and Information Technology of the PRC (MIIT) Guiding Opinions on Strengthening Urban Water Conservation Work
15 April 2022	MOF, MOHURD, MWR Published the "Notice on Carrying out the Second Batch of '14th Five-Year Plan' Systematic and Global Promotion of sponge city Construction Demonstration Work"
18 April 2022	General Office of MOHURD Notice on Further Clarifying Relevant Requirements for sponge city Construction Work

Table 1. **Source:** www.gov.cn; www.mohurd.gov.cn; www.mof.gov.cn/index.htm; www.mwr.gov.cn

planning approach, Li and Kim (2022) analysed sponge city projects' impact on Harbin, Quzhou and Sanya, China. The results showed that current sponge city projects could improve the urban climate's warmth (Li and Kim, 2022).

2.4 Sponge city for enhancing water and resources circularity in China

Sponge city development addresses climate change and the water-related challenges of urbanisation (Ma and Jiang, 2022). It solves urban surface water flooding problems and improves urban water resource management (Wang *et al.*, 2021b). Nature-based solutions for sponge city have been promoted as sustainable solutions for urban stormwater management and addressing the urban flooding problem (Fu *et al.*, 2022). To improve the assessment of the hydrological cycle and sponge city's options, Jiang and McBean (2021) used the concept of "One Water" to demonstrate structured thinking about how each dimension of the hydrological cycle could be used to study the degree of interrelationships.

Some scholars discussed the relationship among water elasticity, resources, treatment, ecology, waterscape and management modules based on sponge cities to solve urban water problems and human livability (Wang *et al.*, 2021a). Based on the sponge city plan, six critical processes of water circularity include retention, infiltration, storage, purification, emission and utilisation (Liu *et al.*, 2022) are applied in more than 30 cities in China. The increase in urban greening, urban river and lake wetlands expansion, and rainwater resource utilisation have reduced the city's carbon emissions (Shao *et al.*, 2018). Sponge city can benefit from the circularity issues on water and carbon dioxide.

2.5 Social media – a missing piece in sponge city study

Social media has a considerable global user with a diverse geographic distribution; users can quickly and easily post, comment and repost any message; and information can be found and swiftly shared (Cheng *et al.*, 2019). Thus, natural disaster management and prevention rely heavily on social media analytics. Moreover, four metadata fields in social media data – space, time, content and network – provide helpful information to understand the situation better and respond to disasters (Wang and Ye, 2018). This can overcome the problem of traditional approaches like questionnaires and interviews, which suffer from low response rates (Li *et al.*, 2022).

Research shows that while most people are aware of flooding hazards, they lack awareness and understanding of sponge city initiatives (Zheng *et al.*, 2022). Because the effectiveness of implementing nature-based solutions depends on the participation of a well-informed public, researchers conducted a survey in Wuhan to identify factors that influence public perception of sponge city plans (Zheng *et al.*, 2022). Previous surveys showed that the public's attention, satisfaction and acceptance of sponge cities differed depending on living environments (Luo *et al.*, 2022). Sponge city residents are satisfied with the travel and living conditions and strongly support the local government (Luo *et al.*, 2022). Fu *et al.* (2022) believed that bottom-up community-based approaches are essential to transform sponge cities into flood-resistant ones.

The role of social media in affecting public perception of sponge city was remarked to a different degree. Taking Xi'an China as an example to compare awareness differences of sponge city, Zheng *et al.* (2022) stated that the concept of sponge city was one of the few ways for locals to come across them because it was occasionally mentioned in social media and is not often visible in the streets. Cheng *et al.* (2019) pointed out that during the flooding, the public questioned the efficacy of sponge city investments on social media (Sina Weibo), negatively impacting the mitigation and recovery stage of the flooding disaster.

Sponge city has received public attention for over 10 years (Yin *et al.*, 2021). Although the above studies highlighted people's perceptions, they adopted offline public and community data. Most focus on sponge city's construction, technical aspect and management method. Research about public perceptions of the semant analysis and foci of sponge city is scarce. Thus, there is a research gap in public perceptions about sponge city's foci and sentiment on social media.

2.6 Ecological modernisation city branding and social media

City branding refers to research and management of brands that represent cities which include the research of several branding relevant concept (Molina *et al.*, 2017). A comprehensive understanding of the current city image is the main concern in the first step of city branding (Shirvani Dastgerdi and De Luca, 2019). According to de Jong *et al.* (2018), the ecological modernisation city labels like resilient city and green city appear widely in the academic research and policy and are frequently adopted for promoting ecological modernisation. Sustainability as an additional dominant city-branding narrative has increased in prominence as a result of the discourse on sustainable development (Rinaldi *et al.*, 2021). Cities reflect imperative of ecological modernisation in the branding practices by responding to the ecological modernisation requirements (de Jong *et al.*, 2018).

The way cities can and should communicate and build their local brands has changed, thanks to the internet and its tools, as social media networks allow users to generate the brand content. Social media platforms may be one of the most visible aspects of online branding strategies (Molina *et al.*, 2017).

3. Research method

Recent research has shown that social media is increasingly being used to respond to crises. Using big data and social media to improve flooding preparation and prevention significantly reduced flooding impacts (Chan *et al.*, 2022). Social media is used for disaster preparation, response, mitigation and recovery (Tang *et al.*, 2015; Carley *et al.*, 2016; Cheng *et al.*, 2019). Despite there is an increase in research on using social media in times of different disasters, and there is rare relevant research in China (Cheng *et al.*, 2019).

From 1st January 2011 to 17th September 2022, the study collected Sina Weibo users' information about sponge city (in Chinese "海绵城市") via Python 3.10. Then, the KH-Coder

and CX Data Science of Simply Sentiment were applied for the semantic analysis of Sina Weibo content. The cluster analysis uses the statistical technique, and the frequency of co-word occurrence studies the co-occurrence network and the relationships between various groups. A research field can be inferred intuitively from multidimensional scaling analysis, which determines the topic structure by calculating the distance between topic words (Li *et al.*, 2023). Clustering is accomplished using the KH Coder. This study also reviewed sentiments expressed in the posts via AI into categories like opinions, facts and positive and negative (Song *et al.*, 2022). The method flowchart is shown in Figure 1.

There were 64,693 contents from Sina Weibo's users. After selecting, cleaning and deleting the data not related to "sponge city", 53,586 data were collected. From 2011 to 2016, the government put forward the concept, method and standard of "sponge city". Thus, sponge city microblogs increased and peaked at 8,589 blogs in 2016, with comments recorded high in the same year (data for 2022 is incomplete). The number of likes 151,718 peaked in 2021, which was several times higher than others (Figure 2).

4. Data analysis

4.1 Keywords analysis

After running pre-processing in KH Coder, there are 53,586 paragraphs and 351,375 sentences. When we selected words to analyse, keywords such as sponge city, city, and sponge cities were deleted to enhance popular topic visualisation. This study also included stop words for keywords like the pronoun, prepositions, etc.

4.1.1 Word frequency. This study visualised the top 300 keywords via Tableau 2021.3. Top 50 keywords with higher frequencies are shown in Table 2. From Figure 3, the font size indicates the total number of term frequencies. Among them, water (67,087), construction (66,488), urban (55,944), road (37,952), new (37,925), development (36,049), ecological (28,855), "park" (28,282), "project" (27,752), "green" (27,482), area (27,387), projects (21,906), district

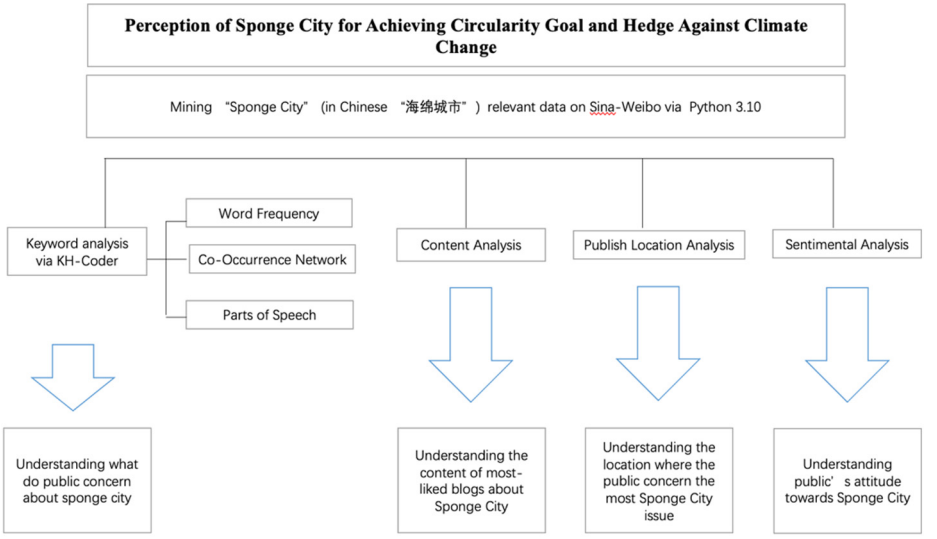
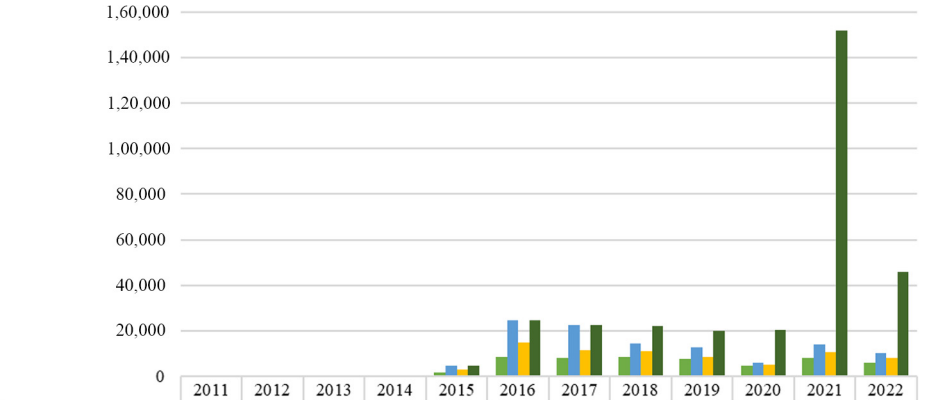


Figure 1.
Method flowchart

Source: Created by author



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of posts	2	6	15	36	1616	8589	8131	8459	7736	4818	8280	5898
Number of forwards	12	72	21	76	4825	24842	22463	14556	12617	5832	14143	10446
Number of comments	6	24	13	39	2941	15101	11369	10947	8416	5314	10666	7935
Number of likes	0	0	2	19	4597	24534	22401	22055	19865	20403	151718	45686

Source: Created by author

Figure 2.
Annual statistics about Sponge city on Sina Weibo

Words	Term frequency	Words	Term frequency
Water	67,087	Design	12,302
Construction	66,488	Improve	12,179
Urban	55,944	Control	12,127
Road	37,952	Technology	11,916
New	37,925	Concept	11,816
Development	36,049	Square	11,701
Ecological	28,855	Comprehensive	11,665
Park	28,282	Protection	11,597
Project	27,752	Link	10,653
Green	27,482	Public	10,395
Area	27,387	Drainage	10,336
Projects	21,906	Environmental	10,247
District	21,042	Quality	10,221
Build	20,430	Demonstration	10,009
River	18,846	Accord	9,670
System	17,556	Treatment	9,555
Management	16,593	Garden	9,469
National	16,147	Permeable	9,351
Planning	16,083	Complete	9,319
Rainwater	15,378	Facilities	9,166
Promote	14,765	Million	8,929
Environment	14,026	Housing	8,823
China	13,830	Pipe	8,717
Landscape	12,821	Billion	8,674
Building	12,411	Community	8,624

Source: Created by author

Table 2.
Top 50 keywords with high frequencies

(21,042), build (20,430), river (18,846), system (17,556), management (16,593), national (16,147), planning (16,083) ranked top 20. Water is the most influential and popular keyword on Weibo. The topic of water in sponge city on Weibo can be classified into five aspects: water safety, resource, environment, ecology and culture. These five topics are the main factors affecting the urban water system in the urban water cycle (Table 3).

4.1.2 Co-occurrence network. Constructing a word co-occurrence network helps analyse the relationship between words and words that appear together in a sentence. The minimum word frequency was set as 5,000, and the minimum document frequency was set as 1. The co-occurrence network is shown in Figure 4. Thirteen clusters focused on three topics:

(1) sponge city's construction;

(2) ecological environment and urban–rural development; and

(3) management by municipal departments and enterprises.

The most significant cluster is water, construction, urban, new, green, area, road, project, district, build, squire, meters, kilometres and space. It is represented by dark blue colour. The largest cluster also links to the cluster in orange, and the second cluster with development, management, promotion, housing, urban–rural and system. The biggest cluster relates to the third cluster with green colour, which includes ecological, park, environment, improve, quality and improvement.

4.1.3 Parts of speech. Figures 5 and 6 show the most frequent adjectives and verbs. Municipal represents that the many blogs are related to governments' systematic planning, report, commitments, implementation, projects, etc. The word "Natural" were usually mentioned: "Natural resource", "Natural Sponge", "Natural surroundings", "Natural accumulation", "Natural purification", "Natural process", "Natural ecological security", "Natural storage", "Natural ecosystems", "Natural disasters", "Natural aquatic organisms", "Natural cycle of water", etc. Natural methods construct a sponge city, and it is based on "Natural ecological security" and "Natural surroundings".

Verbs such as accord, start, take, implement, carry, meet, provide, and include are linked to current urgent construction tasks in sponge city. Other verbs, such as "build", "promote", "improve", "complete", "increase", "create", "become", "strengthen", "live", "lead", "reach" and "continue", are related to the future goals and strategies for sponge city's management and development.

4.2 Content analysis

This study studied the annual most-liked blogs related to sponge city from 2013 to 2022. As abovementioned in Section 3, the most like posts happened in 2021. Sponge city microblogs

Figure 3.
The top 300 keywords with high frequencies

Source: Created by author

Contents about water	Related keywords	Examples from users
Water safety	"purify water", "water control", "water treatment", "water replenishment", "water storage", "water collection", etc	The shortage of drinking water resources and the severe decline of agricultural water and groundwater have issued more serious warnings! For example, User A posted a blog about developing sustainable circular agriculture and sponge city design, as well as vigorously improving the water storage function of reservoirs and canals that are more important in Jinjiang. User B suggested that sponge city refers to a city that is like a sponge and has good ''elasticity'' regarding environmental changes, adaptation and reaction to natural disasters. It absorbs, stores, infiltrates, and purifies water when it rains
Water resource	"circular water resources", "water resources", "renovation of water supply", "water system", etc	User C posted, "Chinese water resources are in short supply, and there is a huge demand for water resources. Rainwater collection and utilisation technology can greatly alleviate the consumption of water resources such as municipal and irrigation water, and can also reduce environmental problems such as urban waterlogging and ecological balance damage". Likewise, another user said that the construction of sustainable and circular water resources is indeed significant
Water environment	"water accumulation point", "regional water elasticity", "water catchment areas", "water body", etc	User D says we should further promote the classification of domestic waste and urban landscaping and eliminate black and smelly water in built-up areas of cities above the prefecture level, making the urban environment more liveable
Water ecology	"ecological water restoration", "water conservancy", "sustainable water", "water conservation", "water balance", "water permeability", etc	User E said there is no water accumulation in summer, and the road surface is bonded with natural stones and colloids, with a water permeability of 70%. There are many green plants in Guixi ecological park, and the design is excellent, which will effectively reduce the heat island effect in the area. You can jog and do morning exercises here. User F said, the project adopts the concept of hydrophilic, living water and good water in Singapore's ABC water plan and combines the advanced experience of Fengxi new town to build according to the local conditions, harmonious human and ecological water restoration, comprehensive management, and implemented by local government divisions

(*continued*)

Table 3.
Detailed information about "water"

Contents about water	Related keywords	Examples from users
Water culture	"water landscape", "water recreation"	User G suggested we "make water conservation a habit in the capital city". User H proposed to include water culture in education. "Fine arts and environmental design graduation exhibition: relying on the original pattern for landscaping and functional arrangements, and then extracting the site's history and culture memory, integrated into the design details, it forms a coherent campus ecological network system based on water, and creates a place for teachers, students and residents to watch, rest and play"

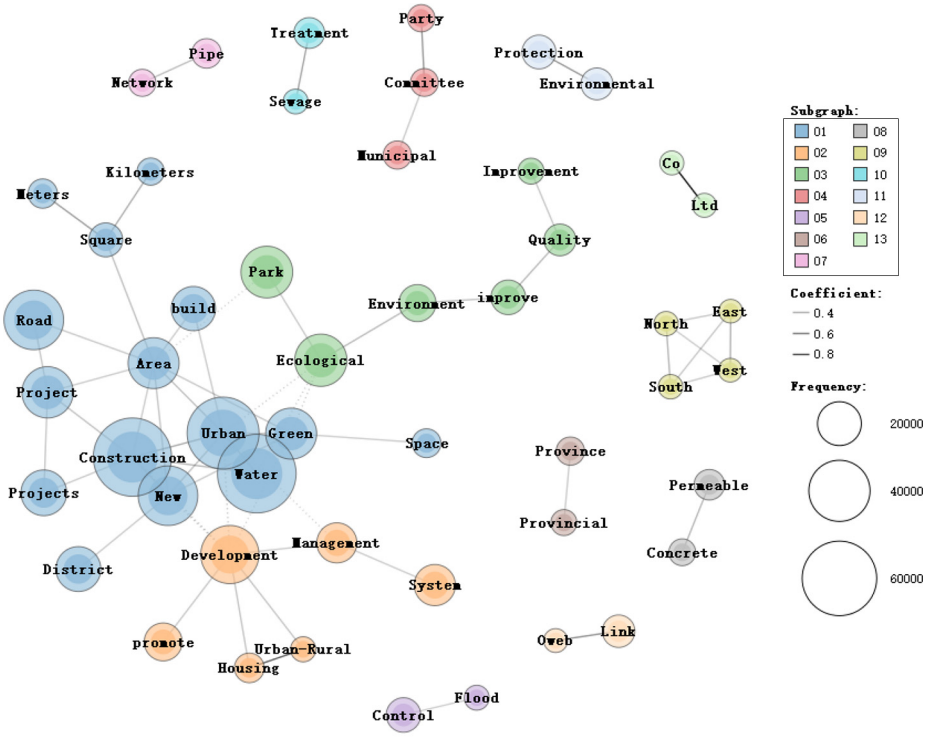
Table 3. **Source:** Created by author; https://m.weibo.cn/

peaked at 100,390 in 2021 (Table 4). Table 4 describes good news about China's Construction Second Bureau Qilu Branch winning one provincial engineering construction method in Shandong Province. The user shared sponge city knowledge and "PDS Anti-siphon Drainage Collection System Construction Method". This kind of knowledge sharing is popular with the public on Weibo and benefits the public, sponge city managers and governments.

On the contrary, some negative blogs attracted many likes (Table 4). Sheng**'s blog, with 2,623 likes, reported that the central investigation team revealed that Zhengzhou spent ¥50bn on the "sponge city" project, but only 32% of it was used in related projects. He added that it did not seem to have any effect during heavy rain. But many experts pointed out that similar views were biased. The severe rain disaster in Henan this time was very rare. One-third of last year's rainfall fell within one day. The amount of rainfall exceeded the ability of the sponge city to deal with it, and it has nothing to do with the sponge city. The recurrence period of the waterlogging prevention and control design in Zhengzhou city matches the city scale. If it is designed according to this extreme situation, it will cause serious waste of resources. Gu**'s blog, with 4,702 likes, mentioned Beijing's rainwater in 2020. It is similar to Zhengzhou's case. A blog with 921 likes was posted in 2016. Since the second half of 2015, due to the sponge city project, rail transit construction and elevated road construction in Jinan City, roads are frequently repaired, resulting in extreme traffic congestion for a long time, and many Jinan citizens have been angry. People suggested that "Jinan should be blown up and rebuilt". Despite controversies, the Jinan Municipal Government did not remove the posts but actively responded to public comments.

4.3 Publish location analysis

Among 286 locations, this study selected the top 30 sites with higher frequencies. Thirty popular sponge cities on Weibo are as shown in Figure 7. Beijing (203), Xi'an (157) and Zhengzhou (102) ranked top 3. 17 out of 30 pilot sponge cities recorded the largest number of Weibo posts. Special funds from the central government subsidise these 30 pilot cities. Beijing is the first batch of pilot sponge city in 2016. Besides Beijing, top 30 sponge cities with largest number of Weibo posts include Wuhan (71),



Source: Created by author

Figure 4.
Weibo co-occurrence network in Sponge city

Shanghai (62), Shenzhen (58), Pingxiang (56), Chongqing (53), Suining (49), Guyuan (48), Tianjin (45), Changde (45), Nanning (40), Qingyang (39), Jinan (38), Hebi (36), Chizhou (35), Baicheng (35) and Zhuhai (24) are all pilot sponge cities in China.

The other cities with higher frequencies are not the pilot sponge city, such as Xi'an (157) and Zhengzhou (102). These cities have once suffered from severe rain and flood disasters in recent years, including 7.20 Zhengzhou Heavy Rainstorm in 2021 and 7.24 Xi'an Heavy Rainstorm in 2016. Thus, these cities' citizens posted more microblogs about sponge cities. The city with practices and constructions of sponge cities or some cities that occurred rainwater and urban flooding may become popular and influential cities on Weibo in the context of sponge city research. People live in sponge cities publish more blogs about sponge city than people living in traditional cities.

4.4 Sentiment analysis

To explore the public's attitude towards sponge city, CX Data Science of Simply Sentiment tools analyses the 53,586 contents from Weibo. A total of 58% were positive (+ve) (Figure 8), and only 14% were negative (–ve). Positive sentiment accounted for 76.8%, which was fourth times higher than negative one (18.5%, Figure 9), confirming sponge city might help city branding online. Although Fu *et al.* (2022) held that there is a limit to how much rainfall sponge cities can absorb, they are unlikely to be a panacea for urban flooding problems. Uncertainty in sponge city design and planning and insufficient funding are the most severe issues that can

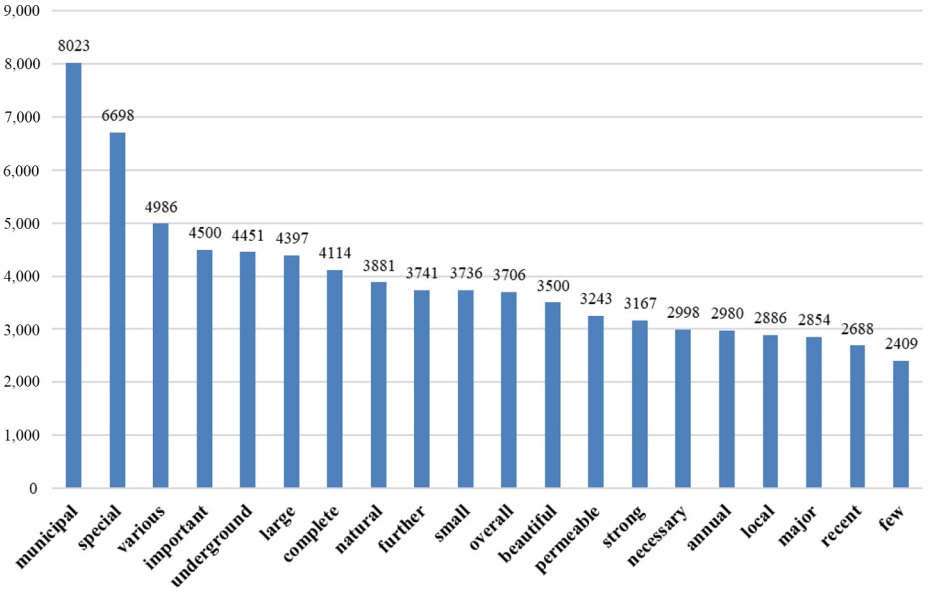


Figure 5.
Frequency of most mentioned adjectives in Sponge city

Source: Created by author

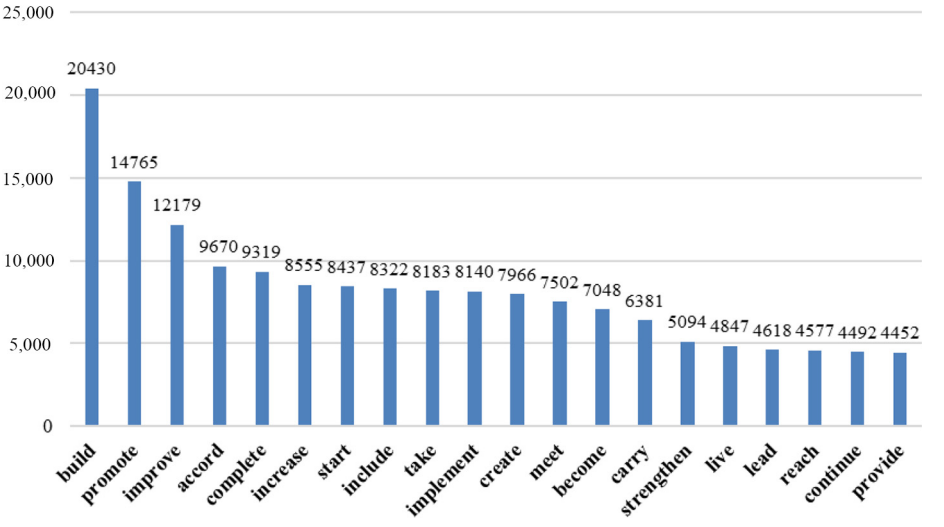


Figure 6.
Most mentioned verbs in sponge city

Source: Created by author

Publish Year	Users	Main content	No. of likes
2013	Fang**	#Fangsuo·Book# What are the basic conditions of a good city? Sponge cities can absorb water, amphibious cities that resist global warming, bicycle lanes protected by on-street parking, and mobile markets that become more crowded with traffic congestion . . . The unique charm of the city is a genuinely beautiful landscape	2
2014	Zhai**	[People's Daily Online: Building a "Sponge City"] Water-scarce cities must manage wasted water. The Ministry of Housing and Urban-Rural Development and the National Development and Reform Commission promote permeable pavement and open green spaces in large-scale development plots to minimise damage to the city's original water ecological environment and build a "sponge city" with natural accumulation, natural infiltration, and natural purification	8
2015	Yang**	[Exposure of the "Underground Palace" in Beijing] Beijing's flood season is from 1st Jun. to mid-September. How to resist heavy rain? Currently, there are 34 such reservoirs in Beijing, and 27 sunken overpasses will be renovated this year. What do you think of the "sponge city" for dealing with rainwater?	1,096
2016	Meng**	[Citizens suggested that "Jinan was blown up and rebuilt" and the Jinan Municipal Government replied] Since the second half of 2015, due to the sponge city project, rail transit construction and elevated road construction in Jinan City, roads have been frequently repaired, resulting in extreme traffic congestion for a long time that made many Jinan citizens angry	921
2017	Guo**	[Yuelai New City will build a smart city for flood control and disaster reduction and early warning] Recently, news from the Liangjiang New District Yuelai Sponge City Construction Promotion Work Conference stated that the "Yuelai New City Sponge City Monitoring Platform" with over 37 million investment for trial at the end of August. The platform can collect sponge facilities operation data in pilot cities, control the whole process of sponge city construction in an all-round way, and improve urban flood prevention, early warning and disaster reduction	465
2018	Ren**	[#Hello Tommorrow#] It rained heavily in many places across the country, and many cities were flooded with golden mountains. The inspection well with the cover lifted is dangerous, and the wires exposed in the water are hard to guard against. To avoid painful surprises, city managers need to be more careful. A sponge city should have sewers with a conscience, and action should come before the rain	3,364
2019	Guo**	[The main urban area will build 427 kilometres of clear water and green banks in 2021] On 6th Jan., the Municipal Government Public Information Network released the "Implementation Plan for the Improvement of "Clear Water and Green Banks" in the Main Urban Area of Chongqing. . .Meet the requirements of sponge city planning indicators, and the green coverage rate of the green buffer zone will reach more than 80%	1,724
2020	Gu**	This is the voice of ordinary people. Yesterday, the Beijing News asked why the city constantly flooded. They all said that the infrastructure was not good enough. It was disgusting! Is the country doing nothing? Sponge city and more! Is the flooding in the USA and Japan also have an infrastructure problem?	4,702
2021	Ji **	[China Construction Second Bureau Qilu Branch won one provincial engineering construction method in Shandong Province] Recently, the "PDS Anti-siphon Drainage Collection System Construction Method" compiled by China Construction Second Bureau North China Company Qilu Branch won	100,390

(*continued*)

Table 4.
Blogs with the annual most likes from 2013 to 2022

Publish Year	Users	Main content	No. of likes
		the Shandong Provincial Provincial Engineering Construction Method. The PDS anti-siphon drainage collection system in this construction method collects infiltrated water and uses it as water for garden irrigation to save water, improve the urban ecological environment and improve urban flood control, drainage and disaster reduction. . .Sponge city follows the six-character policy of "infiltration, stagnation, storage, purification, use, and drainage" . . .	
2022	Sheng**	For example, some time ago, the central investigation team revealed that Zhengzhou spent 50 billion yuan on the "sponge city" project, but only 32% was used on related projects. During heavy rain, it did not seem to have any effect	2,623

Table 4.

Source: https://m.weibo.cn/

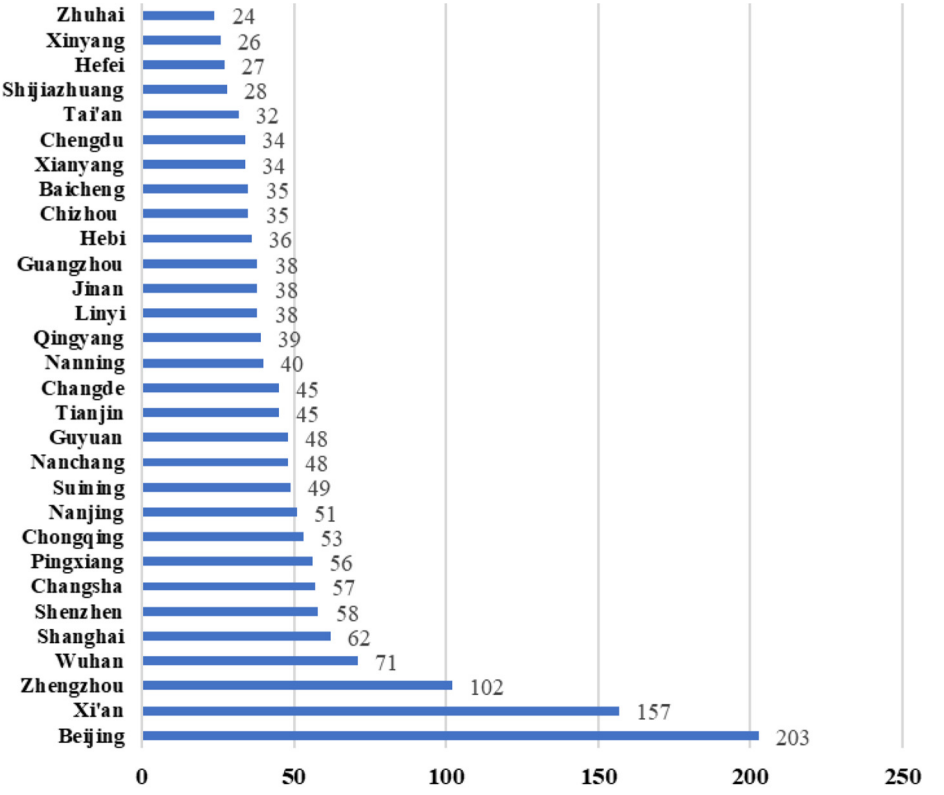
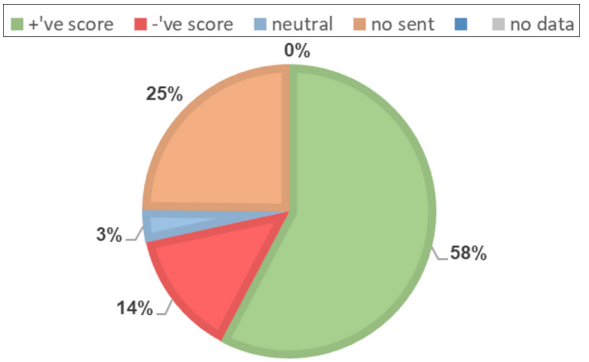


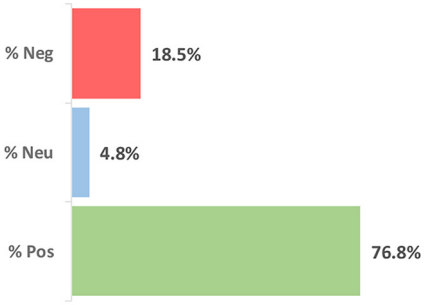
Figure 7.
Publish location of sponge city on Sina Weibo

Source: Created by author



Source: Created by author

Figure 8.
Net sentiment



Notes: Neg: Negative; Neu: Neutral; Pos: Positive
Source: Created by author

Figure 9.
Total items processed

Source: Created by author

Figure 10.
Tag clouds – all sentiment about Weibo users on sponge city

lead to the failure of the sponge city concept (Nguyen *et al.*, 2019). Besides, some people post on Weibo about sponge city with negative attitude (Section 5.2). Most public users were optimistic about the sponge city initiative. Positive sentiments included "improve", "comprehensive", "good", "high quality", "beautiful", "support", "improvement", etc. (Figures 10 and 11), while the negative sentiments consisted of "waste", "problems", "pollution", "problem" "epidemic", "disaster", etc. (Figures 10 and 12). These negative sentiments might provide useful insights for future sponge city plans making or strategies.

5. Results and discussion

The sponge city is closely related to climate issues, especially urban flooding and rainwater hazards. Climate change, Climate change, increased urbanization, and ineffective urban planning regulations have resulted in water-related issues in numerous countries, including flooding hazards, water pollution and water scarcity (Nguyen *et al.*, 2019). Climate change and related issues were frequently mentioned in sponge city. This is related to people's expectations of more hazards will, emerge, cities will face more severe and complex climate change risks, impacting human health, economic development and ecosystem services (Zhai *et al.*, 2019). Likewise, in China, climate change and sustainable urban development are extremely prominent issues (Zhai *et al.*, 2019).

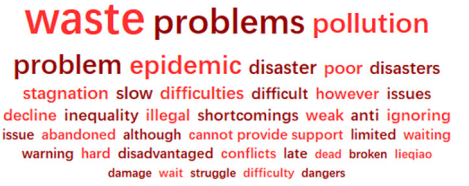
Modern urban flood management includes engineering methods like infrastructure construction and public opinion mining to know more about their perception to ensure better public participation via social media and enhance preparation for flooding and response (Lu *et al.*, 2022).

To answer the first research question, the word frequency results indicated that Weibo's users focused on "water". The co-occurrence networks reflected that "water" remained the most critical issue in sponge city construction. A specific urban water management strategy for a sponge city is a complex approach that faces many challenges (Nguyen *et al.*, 2019). It indicated that water is an essential topic related to sponge cities in public perception. The public focuses on five aspects: water safety, resources, environment, ecology and culture. The former four factors are related to urban water circularity. The essence of sponge city construction should be classified into the category of comprehensive improvement of the five elements of urban water. We need to consider the natural water cycle and social cycle as a whole and construct a sponge city based on national conditions.

To answer the second research question, this study analysed the annually published blogs with the most likes from 2013 to 2022, except for the most popular blogs in 2021, to

Source: Created by author

Figure 11.
Positive sentiment on sponge city



Source: Created by author

Figure 12.
Negative sentiment on sponge city

share knowledge about sponge cities. The sentiment results indicated that 76.8% were positive, meaning that sponge city might be helpful in building a positive city image and enhance city branding. Nevertheless, some blogs criticised certain sponge cities (such as Beijing, Jinan and Zhengzhou) per Table 4 and attracted many likes. For example, the user criticised the sponge city in Zhengzhou but ignored that the rainstorm disaster in 2021 was very rare, and the heavy rainfall exceeded the sponge city's capacity.

According to Thadani *et al.* (2020), given the significant impact of online social media on brand image, PRC has used online social media for urban project promotion like sponge city. That can also encourage public participation in sponge city design and construction and advocate for all stakeholders to work together in water resource cycle and climate change projects. Public involvement in the sponge city design and construction process can be incorporated into the government's strategic planning and city brand building. Besides, while the government might collect public opinion through social media, it is also important to note that some social media content might be biased (Finch *et al.*, 2016).

To answer the third research question, the parts of speech showed that many blogs are related to governments' systematic planning, report, commitments, implementation, projects, etc. The content analysis results reflected that the public and sponge city managers, and governments could benefit from the sponge city's information on Weibo. It proved that the sponge city concept had been communicated to the public. In addition, people who live in sponge cities are more likely to post related blogs. As questionnaires in offline communities were done by Luo *et al.* (2022), residents of sponge cities are generally satisfied with the travel and living conditions and have strongly supported the local government. The online public's perceptions are affected by the living environment's differences. Many writers, who wrote about sponge cities, are those with frequent and severe rainwater and flooding. They are more likely to learn about or even support the sponger city initiative than people elsewhere. As more young people use social media like Weibo, the results may conclude that young people support the sponge cities movement. Moreover, sponge cities' relevant enterprises may pay attention to Weibo for better branding.

6. Conclusion

6.1 Theoretical implications

To assess sponge city's limitations and opportunities, this article critically assesses social media Weibo users' awareness and perceptions of sponge cities. It examines sponge city's popular topics, published locations and the public's sentiment about sponge cities on Weibo. The study revealed the popularity of sponge city on Weibo, contrary to experts who pointed out that sponge city lacks public participation (Wang *et al.*, 2022) . Comparing with the traditional research methods like surveys with offline public people and community, it contains more critical reviews which can improve policies and regulations to incorporate social goals and to include the public in the sponge city-building process.

6.2 Practical implications

The study supports the public's foci and perceptions, especially the five "water" strategies and circularity (safety, resources, environment, ecology and culture) for online governments and city managers. These results will be beneficial in sponge city's decision-making. Moreover, the shift of scholarly attention from city marketing to city branding opens a new era in the representation and meaning of city branding (Thadani *et al.*, 2020). Government can increase online social media publicity and education to cultivate people's awareness of water conservation and make water conservation everyone's action. Related departments can let the public learn about and participate in the sponge city construction. They can also

encourage public on Weibo to actively respond to urban climate change issues, strengthen adaptation and mitigation measures and choose development paths to enhance the city's climate adaptation via the sponge city plan.

6.3 Limitations and future research directions

Although public opinion collection via social media could be faster than questionnaires, the sample data may mainly focus on young people and miss older people who do not use that. Further research might focus on senior public's opinion on sponge city by using traditional research methods like delphi interviews. Besides, it may be possible to apply the same approach to study other topics like smart and low-carbon cities and ecosystem projects that lay a solid foundation for improving carbon sink capacity.

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Further reading

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