



The value of social media tool for monitoring and evaluating environment policy communication: a case study of the ‘Zero-waste City’ initiative in China

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Abstract The construction of a ‘zero-waste city’ is a flagship policy to accelerate the development of a green, low-carbon circular economy system in China. Enhancing social participation is an important dimension to evaluate the effect of ‘zero-waste city’ policy construction and an effective way to promote the full achievement of correct waste classification, management, and supervision of solid waste. Based on policy communication theory, this paper aims to take advantage of social media to quantitatively measure the environment policy communication effect and provide a comprehensive panoramic measurement from dynamic characteristics and trend, communication scope, attributes of communicators, and contents dimensions. Based on post data related to ‘zero-waste city’ on Weibo platforms from June 2018 to November 2020, this paper innovatively constructs a measurement system of environmental policy communication that combines social media data with social network analysis and text topic analysis. Results show that from the angle of communication trend, a ‘zero-waste city’ public environment policy is continuously promoted on social media with an increasingly growing volume and is a subject of wide concern for the public. This study confirms the value of social media data in assessing environment policy

communication effect and presents several policy implications: Government departments should strengthen environmental policy communication by using Weibo and other social media tools to improve the public’s attention toward the policy and increase their participation in environmental governance; focus on people’s livelihood interest in policy communication content; strengthen the interaction of the public with the content of policies by using a popular and understandable public discourse system and encourage multiple social subjects to participate in policy communication and strengthen the communication of the ‘zero-waste’ cultural concept.

Keywords Zero-waste city · Solid waste · Social media · Policy communication · Public perception

1 Introduction

The cumulative amount of solid waste increases year by year with the rapid economic development and acceleration of industrialization and urbanization. At present, solid waste has become a conspicuous global environmental problem (Song et al. 2015). In view of this situation, Australia (Zaman 2015), New Zealand (Robin 2013), the USA (Environmental Protection Agency 2017), Japan (Honma and Hu 2021), the European Union (Romano et al. 2019), and other countries and regions have successively issued solid waste treatment policies and vigorously promoted the creation of a recycling mindset in the society. China not only has a large population but also produces the largest amount of solid waste. Recent statistics show that 196 large and medium-sized cities in China produced more

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than 16.6×10^9 tons of solid waste in 2019 (Ministry of Ecology and Environment of the People's Republic of China 2020). Municipal solid waste management significantly affects human habitats' liveability and public health (Kala et al. 2020).

In recent years, China has acknowledged solid waste pollution prevention and control as important tasks in ecological civilization protection and continuously strengthened the comprehensive control efficiency of solid waste management (Liu et al. 2021). China issued a Work Plan on 'Zero-waste City' Pilot Program and a series of other solid waste prevention and control policies successively in 2018 and 2019 (The state council of The People's Republic of China 2019; Ministry of Ecology and Environment of the People's Republic of China 2019) and selected '11 + 5' cities and regions as the pilots for policy construction. The concept of a 'zero-waste city' is essentially a cyclical urban development concept. This policy aims to encourage society to cultivate an eco-friendly way of life and economic development, reduce solid waste generation and realise resource utilisation.

Strengthening the communication of public environmental policies is an effective means to improve public awareness of ecological issues and shape public behaviour (Zhou and Chen 2019). The public is the main producer of solid waste and the direct victim of environmental pollution (Camilleri 2020). It serves as an important social force to bring ecological pollution under control comprehensively (Garnett and Cooper 2014). Effective policy communication can capture the public's direct feedback and participation in environmental policy governance. And it helps in winning more public support (Kala et al. 2020), to reduce the social management cost of environmental governance and lower the loss of environmental resources caused by market failure and government failure (Zhang 2018). Therefore, based on one-way publicity of traditional media, Chinese government departments have gradually established a point-type network system by using diversified platforms, including government Weibo account, government WeChat, government Twitter, and government apps. This communication system helps in developing environmental policy communication and popularise waste disposal and pollution prevention (Zhao and Du 2013). And the communication process contributes to enhance public awareness of waste disposal issues and shaping the public's collective consciousness in response to environmental problems (Pan and Zhang 2018). However, the effectiveness of environment policy communication based on social media channels is still an open question.

Social media is a promising, powerful, and appealing policy communication channel. Environmental policy communication in social media refers to the process of effective communication and implementation of an

environmental policy by communicating with the public on social media (Xiang and Shen 2021). The contents of policy communication can be summarised as the interpretation of policy content, reports and follow-up news on policy formulation and implementation, discussions derived from policy themes, and content spontaneously disseminated by the public (Canary and Taylor 2020). Environmental policy communication aims to disseminate information accurately and ensure easy access to quality information. And the communication process also emphasises that the government should understand the topics of public concern at both the personal and social levels (Kala et al. 2020). Even through policy communication, governments can guide the public to realize their roles in environmental governance and achieve the purpose of influencing public participation in environmental governance from the perspective of values shaping (Corner et al. 2014). In addition, good policy governance emphasizes transparency and accountability (Xiao et al. 2021). With the nature of strong interaction and high public participation, social media can amplify the voice of the community and public and transmit it to policy-makers to meet the needs of policy governance (Gao et al. 2017). Social media play a vital role in the rapid dissemination of voices from various stakeholders in policy release, implementation and supervision feedback, and other different stages (Yang 2019). Therefore, social media can also be used to evaluate public participation and satisfaction with policy construction (Ministry of Ecology and Environment of the People's Republic of China 2019).

Compared with TV, broadcast, newspaper, and other traditional communication channels, social media enables a two-way connection between the public and policymakers rather than a one-way transmission (Simonofski et al. 2021). The public tends to engage spontaneously on social media with political discussions in a less structured manner (Wei et al. 2021). Different social groups' use of social media jointly expands the scope and connotation of policy communication (Panagiotopoulos et al. 2014). In terms of communication effectiveness, the information conveyed by traditional media and government websites is mostly official and educational but poorly matched to public expectations, leading to a lack of depth of public understanding (Linde 2018). By contrast, using social media for policy communication has a broader audience and better interactivity than traditional ones. Moreover, social media can impact the audience immediately and profoundly (Mah et al., 2014). For policy communication effect measurement, public recognition, public understanding, and the degree of public approval and support for policies are important aspects. However, investigating by field surveys, interviews, or questionnaires is costly. The selection of respondents may also lead to a measurement bias (Ali and

Puppis 2018). For social media, interactions between the public and government departments can generate a huge volume of data. Governments and decision-makers can measure communication and improve decision-making by continuously collecting, analysing, summarizing, and visualizing these data resources on social media platforms (Criado et al. 2013).

Social Network Analysis (SNA) has attracted growing popularity in social media research, since it can provide effective computational techniques to extract valuable information from massive network data (Borgatti et al. 2018). By combining natural language process (NLP) methods, SNA can process multi-modal information from social media and transform unstructured content to structure information (Camacho et al. 2020). In terms of content analysis, user profiling, topic extraction, and sentiment analysis are the most representative applications (Piao and Breslin 2018). Related functions enabled by SNA, such as identifying influential users, user interests, and the abstract theme, have been widely used for healthcare, marketing, cybersecurity, and politics scenarios (Zarrinkalam et al. 2018; Enli 2017; Yang et al. 2019; Mahata et al. 2018). However, studies on public environmental policy communication based on social media analysis are still limited and largely lagged behind the practical demand. Hou et al. (2020) explored the Chinese public's understanding and willingness to support and implement a compulsory garbage classification policy based on the text data posted on China Daily, Weibo, and online platforms regarding the Shanghai garbage classification theme. Building on social media data and modelling, Wu et al. (2021) analysed the emotional tendency of public discussions after implementing the municipal solid waste classification policy. And it further explored the underlying reasons for the public's negative attitude towards the policy. In sum, the existing literature focuses on exploring the public's attitudes towards policies, while the measurements of policy communication are relatively limited.

To compensate for the deficiencies of existing studies, the current research comprehensively measures the effect of the 'zero-waste city' public environmental policy communication from the dynamic trend and scope of communication, attributes of communicators, and contents of communication based on policy communication theory. This study innovatively constructs a measurement framework of public environmental policy communication with social networks and topic analyses of text. Compared with traditional policy communication measurements, the proposed framework has higher feasibility, more comprehensive measurement dimensions, and more quantitative effects. The analysis results depict the characteristics and effects of policy information dissemination in the big data era. This research provides decision-making suggestions

for the communication and promotion of environmental policies and improving public perception and participation effects.

2 Data and methods

This paper proposes a research framework to measure the communication effect of the 'zero-waste city' pilot policy based on social media data. The research framework mainly integrates social network analysis and text mining methods. As shown in Fig. 1, the research process generally consists of data collection, pre-processing, and data analysis.

2.1 Data collection

The 47th statistical report on the China Internet Development shows that the number of Internet users in China has reached 989 million as of December 2020 (China Internet Network Information Center 2021). Social media platforms such as Sina Weibo (hereinafter Weibo), Wechat, and Qzone have become the leading online platform for the public to discuss social issues. Among them, the Weibo penetration rate in China has exceeded 40%. Weibo is also one of the most valued social media platforms by the Chinese government for government affairs. Compared with one-way communication characteristics of traditional media, users can express views and disseminate information via short texts, pictures, and videos on social media platforms. Characterized by rapid information dissemination, high frequency of user interaction, large-scale data, and multi-dimensional attributes, social media are regarded as effective data sources for policy communication measurement (Sun et al. 2016).

In this study, we took China's Twitter—Weibo as the data source to measure the communication effect of 'Zero Waste City' public environmental policy. We request the Weibo advanced search web page by simulating user-login behaviour, with a web page crawler to perform keyword-based data scraping. To ensure the effectiveness and comprehensiveness of data collection, we use 'zero-waste city' as the search query traversing related posts without location restriction. A total of 381,213 posts generated daily from June 2018 to November 2020 were collected, with seven corresponding information items including user's unique identifier, post unique identifier, post URL, geotag, post time, post content, and post forwarding relationship.

2.2 Data pre-processing

The first processing step is deduplicating data according to the post unique identifier. Secondly, we regularly matched and filtered out irrelevant posts to avoid introducing noise

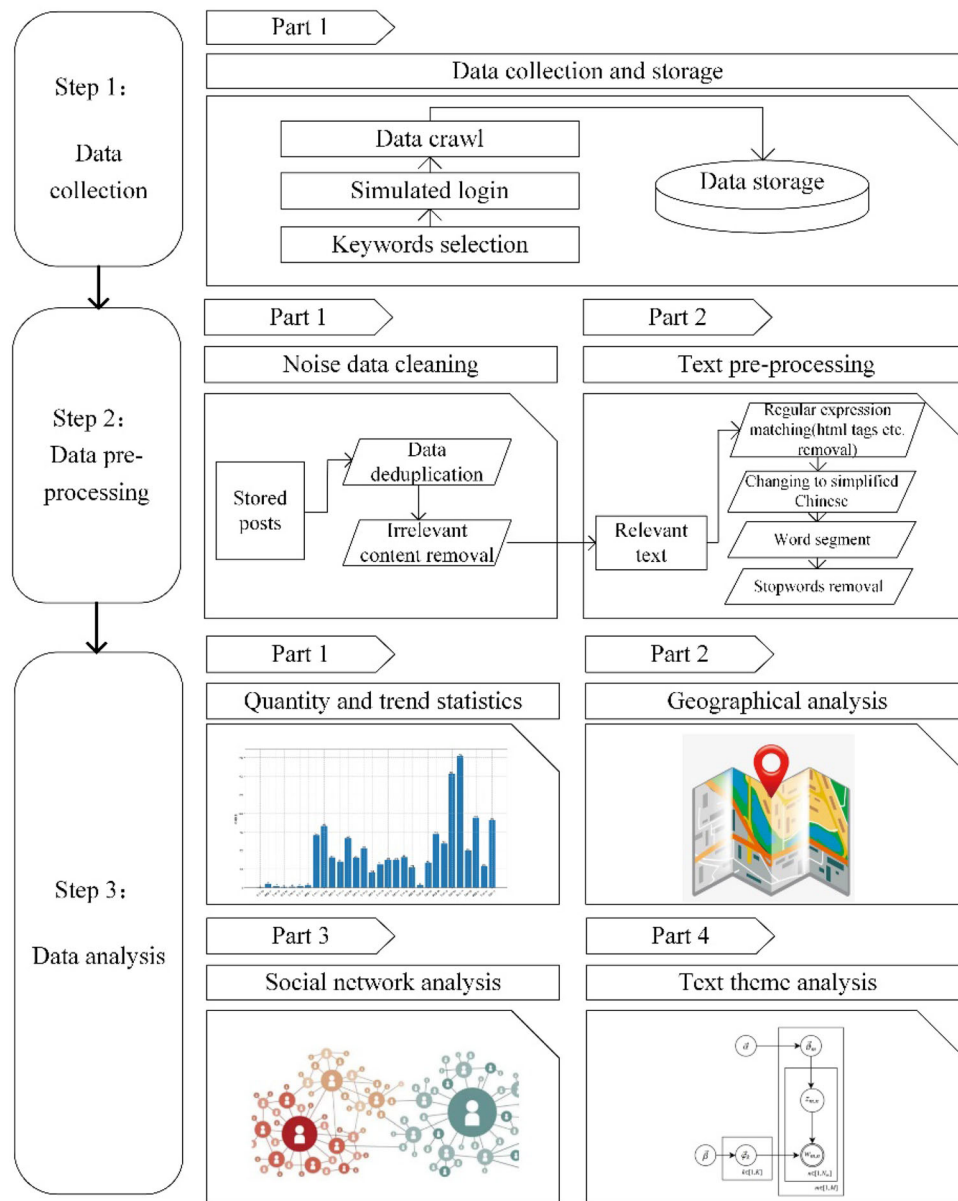


Fig. 1 Research framework

posts, which may contain ‘zero,’ ‘waste,’ or ‘city’ words but topic irrelevant posts. After filtering, a total of 13,634 Weibo posts were retained, involving 5210 topic participants. We further removed URL, usernames, punctuation, and emoji in post contents to avoid bias impact on text analysis. Furthermore, we changed some traditional Chinese characters to simplified characters and conducted word segment and stop-words removal.

2.3 Data analysis and visualization

2.3.1 Quantity and trend statistics

This study estimates the number of posts by their release date to explore the volume and trend of policy information dissemination over time. The results are presented in the form of a bar chart.

2.3.2 Geographical analysis

The ‘zero-waste city’ pilot policy selects ‘11 + 5’ cities and regions in different areas, types, and stages of economic development in China for exploration. For posts with geotags, we took tag information as the geographic coordinates of the posts. And for posts without geotags, the geo-information in profiles was used as geographic information. We analysed the geolocation information of related posts in a two-stage method to identify whether the pilot areas have better policy communication effects than other non-pilot areas. In the first stage, we matched the geo-information and filtered out information such as ‘other’ and ‘overseas.’ We programmed to query the online geographic database GeoNames one by one and converted them into latitude and longitude coordinate pairs for the saved position information. In the second stage, we merged and converted the coordinate pairs into prefecture-level city granularity to keep information heterogeneity.

2.3.3 Social network analysis

In the field of network analysis, the network is composed of edge and nodes, which can be considered as Weibo users in this study. The edges between nodes represent their complex dependency or collaboration relationships. We chose PageRank (PR) as a measure index of the influence of the nodes in the network. PageRank (Weng et al. 2010) algorithm was initially proposed to calculate the importance of web pages based on the hyperlink between web pages. In social networks, there are also links between nodes. When the information published by node A is forwarded by node B, A’s information has obtained attention or approval from B. The more attention and approval node B receives, the more contribution node A gets from B correspondingly. The more node A is forwarded by other nodes, especially nodes with great attention, the more attention or approval node A receives. PR value is calculated as formula (1):

$$PR(p_i) = \frac{1 - d}{N} + d \sum_{p_j \in M} \frac{PR(p_j)}{n(p_j)}, \quad (1)$$

where p_1, p_i, \dots, p_N are Weibo users who participated in the topic discussion. $PR(\cdot)$ refers to the user PR value. M is the set of all users who have reposted the content of p_i . $n(p_j)$ is the number of users who have ever been forwarded by p_j . Therefore, $\sum_{p_j \in M} \frac{PR(p_j)}{n(p_j)}$ is the sum of attention contributed to p_i by all users who have forwarded user p_i . d is the damping factor for formula correction (taking empirical value 0.85).

2.3.4 Policy communication content analysis

To identify the difference between policy dissemination and public policy perception, this study categorized topic participants into individual and non-individual classes according to their registered gender information. Furthermore, we performed text topic analysis (Latent Dirichlet Allocation, LDA) on post content to cluster the concerned topic of users.

3 Results and discussion

3.1 Dynamic characteristics and trend of communication

In this paper, quantitative statistics are developed on 13,634 related Weibo posts according to the release time to identify the time trend of policy information dissemination. In Fig. 2, the abscissa is the month, while the ordinate is the number of Weibo posts. In the figure, the numeral refers to the number of the related Weibo posts in this month. The figure shows that since the state issued relevant policies at the end of 2018, the content on ‘zero-waste city’ published on Weibo increased significantly. Compared with the volume in the six months before the policy was released, the posts increased from a monthly average of 30 Weibo posts in 2018 to a monthly average of more than 400 Weibo posts in 2019. Within two months after the release of the policy, the number of relevant themes reached more than 600 per month, indicating that the policy information spread rapidly on Weibo and was a topic of concern. Since 2020, except for February (the public’s attention shifted at this time possibly because of COVID-19), almost 800 pieces of relevant content were posted every month. From June to September 2020, related posts on Weibo reached a monthly average of nearly 1,000, indicating the further improvement of disseminating policy information capacity and public attention on the concept of ‘zero-waste city’.

From the time trend of communication, the communication process of the ‘zero-waste city’ policy can be divided into three stages. From January to February of 2019, the policy spread rapidly on social media platforms as soon as released. From then to the first half of 2020, policy communication was relatively smooth. In the second part of 2020, the dissemination capacity increased significantly again, with a sharp growth in June and July.

3.2 Communication scope

In the selection of pilot areas, the government comprehensively considered national strategic planning, the levels of economic development and industrial characteristics, the motivation of the local government, and other factors. And the following eleven cities are selected as pilot areas for the construction of zero-waste cities: Shenzhen of Guangdong Province, Baotou of Inner Mongolia Autonomous Region, Tongling of Anhui Province, Weihai of Shandong Province, Chongqing (main urban area), Shaoxing of Zhejiang Province, Sanya City of Hainan Province, Xuchang of Henan Province, Xuzhou of Jiangsu Province, Panjin of Liaoning Province and Xining of Qinghai Province. The government adopted the Xiong'an New Area of Hebei

Province, the Beijing Economic and Technological Development Zone, China-Singapore Tianjin Eco-city, Guangze County in Nanping, Fujian Province and Ruijin in Ganzhou of Jiangxi Province as special cases. Figure 3a. To identify whether the pilot construction area has more powerful policy communication, this paper analyses the location information of Weibo posts. A total of 12,495 relevant Weibo posts were located in the Chinese mainland, accounting for about 91.6% of the total number of Weibo posts. Figure 3b shows the visualisation effect of location information after analysis and processing.

In Fig. 3b, the colour of provincial-level regions changes from yellow to green, indicating that the number of Weibo posts published in the region gradually increased. The spots in the figure represent the corresponding prefecture-level cities. A darker colour indicates a higher number of relevant Weibo posts in the city.

At the provincial level, Shandong (2,924 posts), Beijing (1,106 posts), and Chongqing (1,104 posts) are the three locations that published the greatest number of Weibo posts related to 'zero-waste city'. The number of Weibo posts in Shandong is considerably higher than in other regions. Zhejiang Province, Henan Province, Sichuan Province, Jiangsu Province, Guangdong Province, Tianjin, and Hunan Province rank 4th to 11th in the number of Weibo posts, ranging from 300 to 800. There was no city from Sichuan Province and Hunan Province included in the pilot scope. Nevertheless, the two provinces published more relevant Weibo posts (i.e., 680 and 325, respectively), indicating that they spontaneously focus on work related to 'zero-waste city'. Additionally, the aforementioned provinces rank in the top 10 Chinese mainland provinces in terms of GDP in 2019 and 2020. That is, they are regions

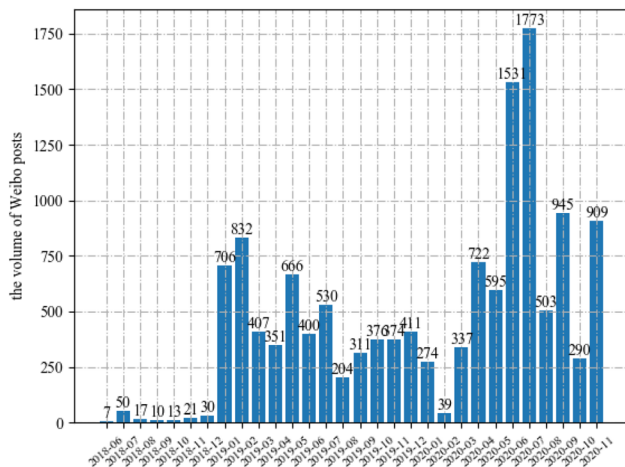


Fig. 2 Time trend in the number of related Weibo posts

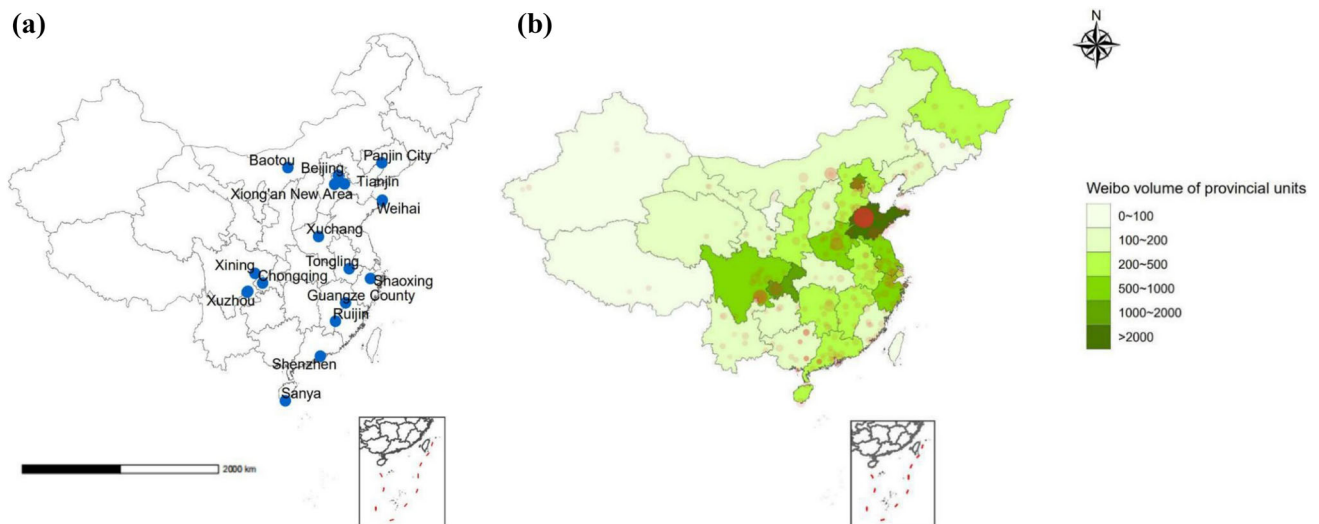


Fig. 3 a Geographical distribution of pilot cities. b Spatial distribution of relevant Weibo posts

with high-level economic development. Amongst the provinces involved in the pilot construction area, Inner Mongolia Autonomous Region, Fujian Province, Qinghai Province, and Liaoning Province have relatively minimal communication, with only 100 to 200 Weibo posts. This situation indicates that the public and organisations of the four provinces are weak in policy communication by using Weibo posts. These provinces, except Fujian Province, have relatively low-level economic development. This finding is consistent with the report on local government microblog communication effectiveness proportionate to economic growth (China Internet Network Information Center 2021).

At the city level, approximately 45% of all Weibo posts are located in city granularity. On the basis of the distribution of Weibo posts, the cities with the most number of blogs are Jinan in Shandong Province (758) and Yibin in Sichuan Province (312). However, both cities are not included as pilot cities. The pilot regions, including the Beijing Economic and Technological Development Zone, Sino-Singapore Tianjin Eco-city and Xiong'an New Region, are not administrative regions. The majority of the Weibo posts published from these areas are classified into Beijing, Tianjin, and Baoding City. Xuchang in Henan Province has the most Weibo posts (228), ranking third at the city level amongst other pilot cities. A total of 107 Weibo posts were published from Tongling and Shenzhen (ranking 10th at the city level), less than that in some non-pilot cities, including Jining and Dezhou in Shandong Province, Xiangtan in Hunan Province, and Hangzhou in Zhejiang Province. The numbers of Weibo posts of Chongqing, Weihai, Baotou, Xining, Sanya, Xuzhou, Shaoxing, and Guangze County in Fujian Province are in the range of 60 to 90, ranking 15th to 30th at the city level. From the overall distribution, the relevant policy information of 'zero-waste city' was widely spread and discussed in the Beijing–Tianjin region, Shandong, Henan, Yangtze River Delta, and Chengdu Chongqing region.

From the spatial scope of communication, regional differences exist in the 'zero-waste city' policy communication. Provinces with a high level of economic development, including Shandong, Beijing, Chongqing, Zhejiang, and Henan, have the highest communication intensity. Zhejiang and Henan. Sichuan and Hunan, which do not have pilot cities, paid attention to and disseminated information about the policy. Among the pilot cities, Xuchang, Tongling, and Shenzhen have the highest policy communication intensity.

3.3 Attributes of communicators

The attributes of social media users who participated in policy communication are analysed in this paper. The

collected posts indicated that a total of 5,476 forwarding relationships could be traced, involving 5,210 Weibo users.

In this paper, PageRank values of all users who participated in the 'zero-waste city' policy information communication network are calculated based on formula (1). The attributes of the top 100 Weibo users are distinguished according to their brief introduction. The users are 64 official accounts of government departments (G type), five media accounts (M type), six corporate accounts (C type), twenty-two individual accounts (I type), and three non-governmental organisation (NGO) accounts (O type). Table 1 lists 20 users with the top PageRank values, indicating the most influential users in this topic network.

The user categories in the table show that the most influential users in policy information communication on the topic of 'zero-waste city' are official government accounts (especially the environmental protection department). The top 8 users in the list are G type, including one state-level government department, three province-level government departments, and four municipal government departments. Only two media users belong to the top 20 PageRank list: China Environmental News and the People's Daily. Two corporate accounts—Crest and Anhui Branch of Sinopec—rank fourth and 10th, respectively. Three individual users are among the top 20 PageRank list, including the actor Bai Yu and his fans and an environmental protection technology practitioner. Three users have similar PageRank values, indicating that they have an equivalent influence in the topic network.

The 'zero-waste city' policy communication network shows that, on the basis of quantity, the public accounts of many government environmental protection departments formed a greater influence compared with some users of media, individuals, enterprises and NGO users, who also participated and formed a certain influence in the network.

The forwarding relationship in policy communication is further visualised in the form of a network graph (Fig. 4). In the figure, a node represents the social media user. The size of the node represents the PageRank value of the user, and the colour of the node represents the attribute of the user. The line between nodes indicates that a forwarding relationship exists between the two nodes. The thickness of the line represents the forwarding frequency, and the arrow of the line points to the user being forwarded. The colour of the line is the same as that of a node on a certain end, indicating that the content published by the node was forwarded by the other node.

Two evident clusters are found in the centre of Fig. 4. In the cluster centred on the 'Chongqing Ecological Environment Department' node (provincial G type node), 'Banan Ecological Environment Bureau' (municipal G type node) and 'Environmental Protection App' (provincial G type node) with a high PageRank value forwarded it

Table 1 top 20 users with PageRank value

No	Weibo User	PageRank value	User type (profile of certificated users)
1	Chongqing Ecological Environment Department	0.261075	G (the official accounts of provincial government department)
2	the Ministry of Ecology and Environment of China	0.162523	G (the official accounts of state-level government department)
3	Banan Ecological Environment Bureau	0.089174	G (the official accounts of municipal government department)
4	Environmental Protection App	0.044744	G (the official accounts of provincial government department)
5	Shandong Ecological Environment Department	0.01379	G (the official accounts of provincial government department)
6	Jinan Ecological Environment	0.007784	G (the official accounts of municipal government department)
7	Linyi Ecological Environment Bureau	0.006378	G (the official accounts of municipal government department)
8	Ju County Environmental Protection Bureau	0.005306	G (the official accounts of district government department)
9	China Environmental News	0.004248	M (the official account of China Environmental News)
10	Anhui Branch of Sinopec	0.003814	C (the account of Sinopec Sales Co., Ltd. Anhui Petroleum Branch)
11	Voice of Beijing Environment	0.003541	G (the official accounts of provincial government department)
12	Civilization Xuchang	0.003404	G (the official accounts of municipal government department)
13	Shangcheng Information Release	0.003377	G (the official accounts of district government department)
14	Crest	0.002799	C (the account of Crest)
15	Dezhou Ecological Environment Bureau	0.002677	G (the official accounts of municipal government department)
16	Baitiansu	0.002498	I (fan of actor Yu Bai)
17	Yu Bai	0.00244	I (actor Yu Bai)
18	Zhonggang Yang—EP	0.002332	I (an employee of Beijing Tiangong Heyi Environmental Protection Technology Company)
19	Jining Ecological Environment Bureau	0.002325	G (the official accounts of municipal government department)
20	the People's Daily	0.002218	M (the official account of the People's Daily)

numerous times, but other surrounding nodes are sparse. This finding indicates that this node has a high PageRank value because a few nodes with a high PageRank value forward and confirmed the information. Moreover, this

finding shows that the Chongqing Ecological and Environmental Protection Department and its subordinate (i.e. Banan Ecological and Environmental Protection Bureau) formed a relatively close communication and receiving

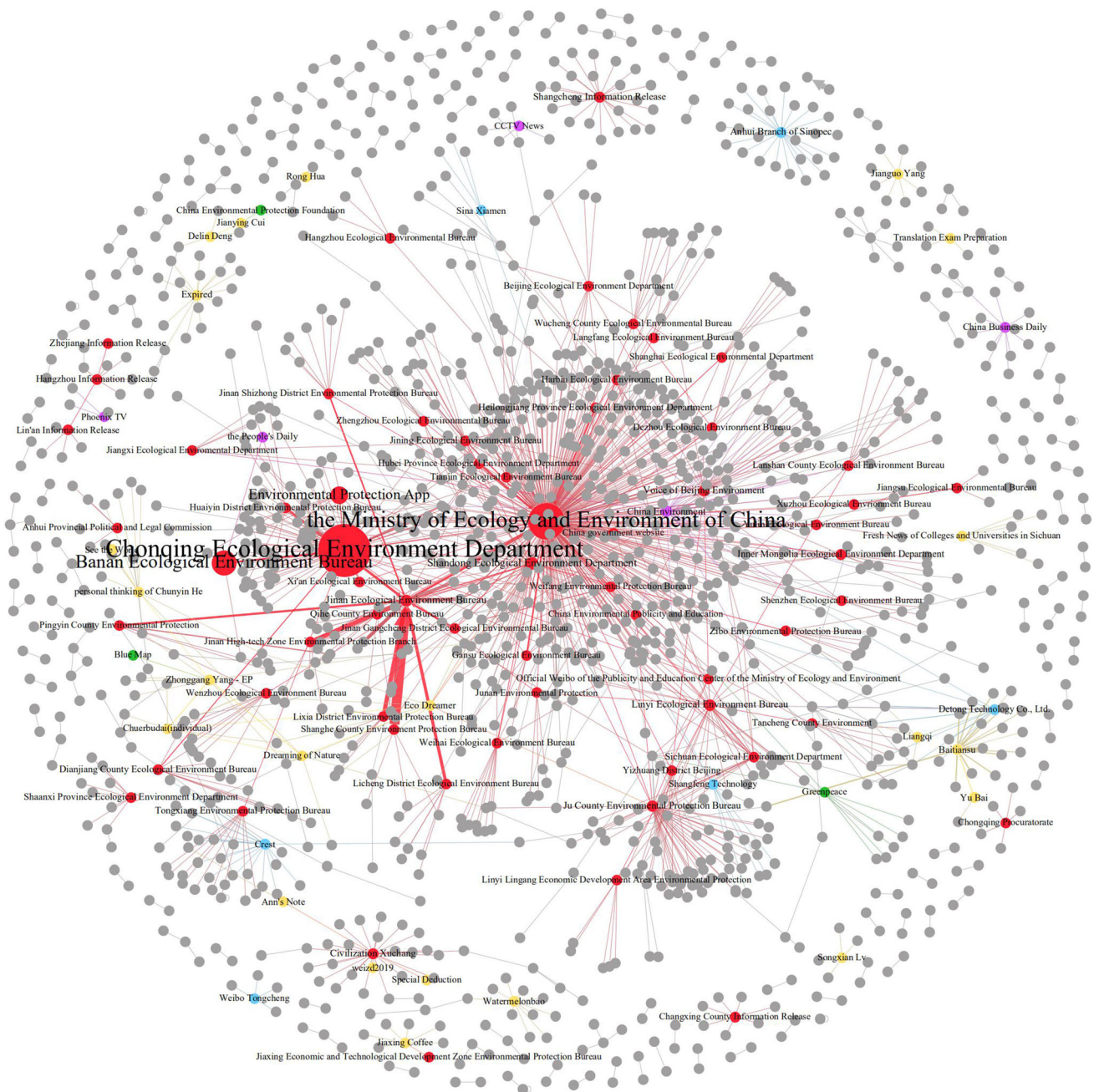


Fig. 4 Forwarding relationship network of relevant Weibo posts. *Note:* Among the top 100 users on the PageRank value, red—G type, yellow—I type, blue—C type, purple—M type, green—O type. Among the users excluded in the top 100 PageRank, grey—other users

relationship with the environmental protection information release platform jointly built with Chongqing Daily and that they jointly disseminated ‘zero-waste city’ policy information. In the cluster centred on the ‘Ministry of Ecological and Environmental Protection’ node, the centre node is surrounded by numerous grey nodes, thereby indicating that the PageRank value of the user is slightly lower than that of users of ‘Chongqing Ecological Environment Department’. However, the policy information released is a subject of concern and forwarded by more

nodes, and the scope of policy information communication is wider. The lines of ‘Beijing Ecological Environment Department’ (provincial G type node), ‘Hubei Ecological Environment Department’ (provincial G type node), ‘Tianjin Ecological Environment Bureau’ (provincial G type node), ‘Jinan Ecological Environment Bureau’ (municipal G type node), ‘Gansu Ecological Environment Department’ (provincial G type node) and ‘Heilongjiang Province Ecological Environment Department’ (provincial G type node) connected with this node are thick. This result

indicates that the official Weibo posts of environmental protection departments at the provincial and municipal levels actively forwarded and disseminated the relevant policies issued by the ecological environment departments at a higher level. Numerous thick lines from district G type nodes ‘Shanghe County Environmental Protection Bureau’, ‘Licheng District Ecological Environment Bureau’, ‘Pingyin County Environmental protection’, ‘Lixia District Environmental Protection Bureau’, ‘Jinan high-tech Zone Environmental Protection Branch’, ‘Huaiyin District Environmental Protection Bureau’, ‘Jinan Shizhong District Environmental Protection Bureau’, ‘Jinan Gangcheng District Ecological Environment Bureau’ and other nodes point to the ‘Jinan Ecological Environment Bureau’ municipal G type node at the lower left of the centre of the figure. This result indicates that the municipal Jinan Ecological Environment Bureau and its subordinate environmental protection bureaus provided considerable public policy information through frequent interactions.

Red lines are mostly shown in Fig. 4, indicating that the policy information released by government public accounts was forwarded numerous times in the communication network of the topic. Purple lines around the ‘China Environment’ M-type media node indicate that other users forwarded content from China Environment Daily. More content from China Environment Daily was forwarded compared with other M type media nodes, such as The People’s Daily, China Business News and Phoenix TV. A total of 22 I-type individual users (yellow nodes) are amongst the top 100 users based on PageRank values, including movie stars, environmental protection technology practitioners, industrial agglomeration researchers, and members of environmental protection organisations. Yu Bai and his fan ‘Baitianshu’ are the most influential in this topic network. They indirectly forwarded information on Yu Bai’s participation in the commercial activity ‘Zero-waste Life, Leading Youth’ hosted by Crest (C type corporate node) to publicise the concept of ‘zero-waste city’ amongst his fans. For corporate users, Sinopec subsidiary, Sina subsidiary, and two environmental protection technology companies are amongst the top 100. This phenomenon indicates that the waste disposal industry and enterprises involved in constructing a ‘zero-waste city’ also participated in the topic network developed a specific discourse influence. The green node represents NGOs, including China Environmental Protection Foundation, the international environmental protection organisation Greenpeace and public environmental protection research projects. However, these organisations have relatively less influence on the network and are fewer in number.

The attributes of communicators indicate that many types of participants exist in the communication network of ‘zero-waste city’ policy information. Media, enterprises,

the public and NGOs participated in policy information communication and discussion and formed different influences. Government public users are dominant in number and discourse influence. The ecological environment departments of various cities, with the official account of the Ministry of Ecological Environment as the core, forwarded and distributed policy information. In particular, the ecological environment departments of Chongqing and Jinan formed a strong interaction and transmission mechanism with their subordinates.

3.4 Communication contents

To further distinguish the participation of the public and organizations in policy communication, we merge the Weibo users into two categories on the basis of the registration information of Weibo users: individual type and non-individual type. Governments, media, enterprises, applications, organisations, public services, campus organisations, and websites are collectively called non-individual type users. This paper classifies the users in the ‘zero-waste city’ policy information communication network, as shown in Fig. 5. About 43% of all Weibo users that participated in the relevant policy communication are non-individual users, accounting for a large proportion of the topic participants. Among individual users, 34% of users are male, and 23% are female. From January 2019 to November 2020, a total of 8,721 posts were posted by enterprise users. The red line in Fig. 6 represents the proportion of posts published each month since 2019. Except for February 2020, posts published by non-individual users every month account for more than 50% of the number of posts in the current month. Moreover, non-individual users continuously publish or forward information in ‘zero-waste city’ policy communication.

In this paper, the post texts published by individual and non-individual users are mined by using the LDA (Latent Dirichlet Allocation) text topic analysis model to identify the point of focus and differences between the two participant groups. A necessary assumption is that the number of topics K of the text corpus is known in applying the LDA topic model. Here, the perplexity measure (Blei and Lafferty 2007) is adopted to judge the optimal selection of the number of topics to avoid affecting the influence of topic classification. The two lines in Fig. 7 represent the decrease in the perplexity of Weibo texts published by individual and non-individual users with a gradual increase in topics K , respectively. The test results show that when the number of topics posted by individual users increases from 1 to 4, the degree of perplexity reduces significantly. However, when the number of topics published by non-individual users is 2, the degree of perplexity decreases significantly. If the degree of perplexity is smaller, then the discrimination effect is

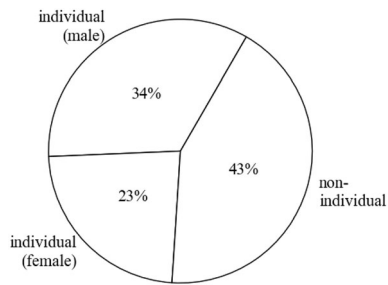


Fig. 5 Categories of Weibo accounts

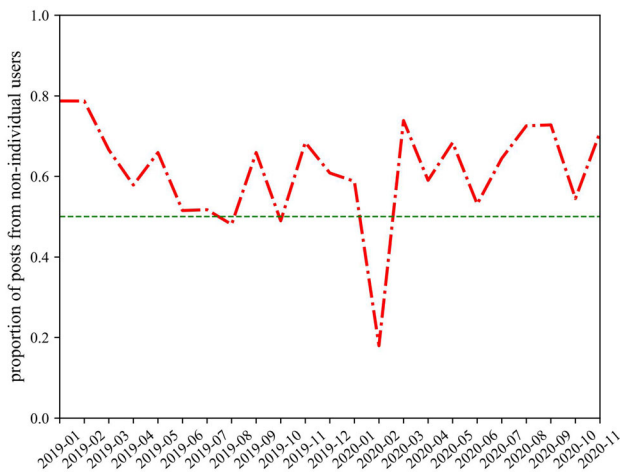


Fig. 6 Proportion of information posted by non-individual users

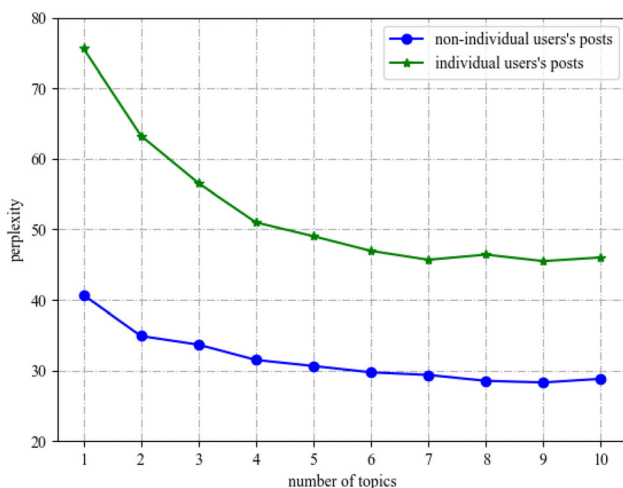


Fig. 7 Number of topics and perplexity of two categories of Weibo posts

better. However, an excessive increase in the number of topics in exchange for the decrease in perplexity will also cause the topics to converge excessively. Therefore, the numbers of topics published by individual and non-individual users are selected as 4 and 2, respectively.

Table 2 shows that the 20 most frequent verbs and nouns with practical meaning are retained as keywords for each topic to reveal the communication content. The LDA topic model assumes that a document set comprises articles with a certain number of latent topics. Each article consists of a mixture of topics, which are represented as a distribution of words. By learning the text corpus of posts, the model generates a word distribution under each topic. Decimals in Table 2 are the corresponding frequency of words in different topics. We can infer the meaning of each topic based on its high-frequency words. The numbers of relevant Weibo posted by the two user categories and the proportion of each topic of posts in the total number of posts in the current month, from January 2019 to November 2020, are shown in Fig. 8.

The keywords in each topic in Table 2 shows that the contents of individual users are as follows: solid waste treatment technologies and projects (Topic A), forwarding of policy information (Topic B), discussion on garbage sorting and recycling and other community activities (Topic C), and spreading information about public welfare activities of celebrities (Topic D).

On the basis of the two subgraphs in Fig. 8b and d, the extent of the public's discussion and spread of 'zero-waste city'-related information is maintained at 100 to 200 per month, with Topic B (forwarding of policy information) as the main content. Relevant posts from January to March 2020 are fewer, focusing on Topic A (solid waste treatment technologies and projects), and substantially increased from June to July 2020. At that time, the proportion of the texts of Topic D (public welfare activities of celebrities) considerably increased, indicating that the increase in Weibo posts during this period was mainly caused by the participation of movie stars in related public welfare activities. Some public individuals observed relevant information on 'zero-waste city' policy construction through these events.

The findings show that individuals' dissemination of and attention to 'zero-waste city' policy information are continuous behaviours, except for the shift in public attention during the COVID-19 pandemic. Celebrity's public welfare activities in cooperation with commercial brands can substantially enhance the public's attention to the 'zero-waste city' relevant concept. Content on community resource recovery activities accounts for a small proportion of the public's content, thereby reflecting the relatively insufficient link between the 'zero-waste' concept and the lives of the public. Some contents were posted on domestic waste disposal, but domestic waste is only a part of the 'zero-waste city' policy construction. The topic network rarely reflects the contents of industrial solid and rural wastes.

Regarding non-individual users' participation, their published posts mainly focus on sharing and interpreting policy information (Topic 1) and promoting the policy

Table 2 Keywords in each topic of Weibo posts

User	Topic classification	Top 20 keywords in each topic
Individual User	Topic A (Solid waste treatment technology and projects)	0.031*“environment protection” + 0.024*“utilize” + 0.021*“investment” + 0.019*“cooperate” + 0.018*“technology” + 0.017*“garbage” + 0.016*“hazardous waste” + 0.015*“project” + 0.015*“desulphurization” + 0.013*“solid waste” + 0.013*“landfill” + 0.013*“enterprise” + 0.012*“coal saving” + 0.012*“include” + 0.011*“fly ash” + 0.011*“handle” + 0.011*“intermediary” + 0.011*“product” + 0.010*“government” + 0.010*“sludge”
	Topic B (Policy information forwarding and dissemination)	0.059*“zero-waste city” + 0.037*“construction” + 0.023*“pilot” + 0.019*“city” + 0.010*“solid waste” + 0.010*“green” + 0.010*“development” + 0.009*“promote” + 0.008*“the Ministry of Ecology and Environment of China” + 0.008*“nationwide” + 0.007*“tour” + 0.007*“zero waste” + 0.007*“Xuchang” + 0.007*“life” + 0.007*“ecology” + 0.006*“promotion” + 0.006*“video” + 0.006*“pilot work” + 0.006*“environment” + 0.005*“solid waste”
	Topic C (Community public welfare activities such as waste sorting and recycling)	0.015*“waste” + 0.014*“zero waste” + 0.010*“environment protection” + 0.009*“waste sorting” + 0.005*“the world” + 0.005*“waste recycle” + 0.004*“public welfare” + 0.004*“community” + 0.004*“China” + 0.004*“Chongqing” + 0.003*“resident” + 0.003*“exhibition” + 0.003*“Beijing” + 0.003*“Coca Cola” + 0.003*“practice” + 0.003*“conduct” + 0.003*“concern” + 0.003*“old” + 0.002*“turn waste into treasure” + 0.002*“Bupingfan (a public welfare activity to turn coke bottles into treasure)”
	Topic D (Information dissemination of celebrity business activities)	0.032*“Yu Bai” + 0.029*“Environment protection” + 0.017*“take action” + 0.015*“earth” + 0.014*“brand” + 0.014*“waste free life” + 0.013*“ambassador” + 0.013*“Crest” + 0.010*“one kind” + 0.009*“daily” + 0.008*“pioneer” + 0.007*“youth” + 0.007*“together” + 0.007*“Yixing Zhang” + 0.007*“call” + 0.006*“compound” + 0.006*“package” + 0.005*“China Environmental Protection Foundation” + 0.005*“paper base” + 0.005*“resource”
Non-individual User	Topic 1 (Policy interpretation information forwarding)	0.013*“construction” + 0.013*“solid waste” + 0.011*“zero waste city” + 0.011*“waste” + 0.007*“environment” + 0.006*“work” + 0.006*“sort” + 0.006*“management” + 0.005*“pollution” + 0.005*“treatment” + 0.005*“the Ministry of Ecology and Environment of China” + 0.005*“life” + 0.005*“utilize” + 0.005*“green” + 0.005*“system” + 0.004*“ecology” + 0.004*“disposal” + 0.004*“prevention and cure” + 0.003*“solid waste” + 0.003*“reform”
	Topic 2 (Propaganda for policy promotion)	0.094*“zero waste city” + 0.032*“tour” + 0.024*“pilot” + 0.016*“the Ministry of Ecology and Environment of China” + 0.014*“programme” + 0.013*“green” + 0.011*“development” + 0.010*“district” + 0.008*“promotion” + 0.008*“implement” + 0.008*“request” + 0.007*“video” + 0.007*“recommend” + 0.007*“jointly with” + 0.007*“department” + 0.007*“candidate” + 0.007*“every province” + 0.007*“screen” + 0.006*“grant” + 0.006*“pattern”

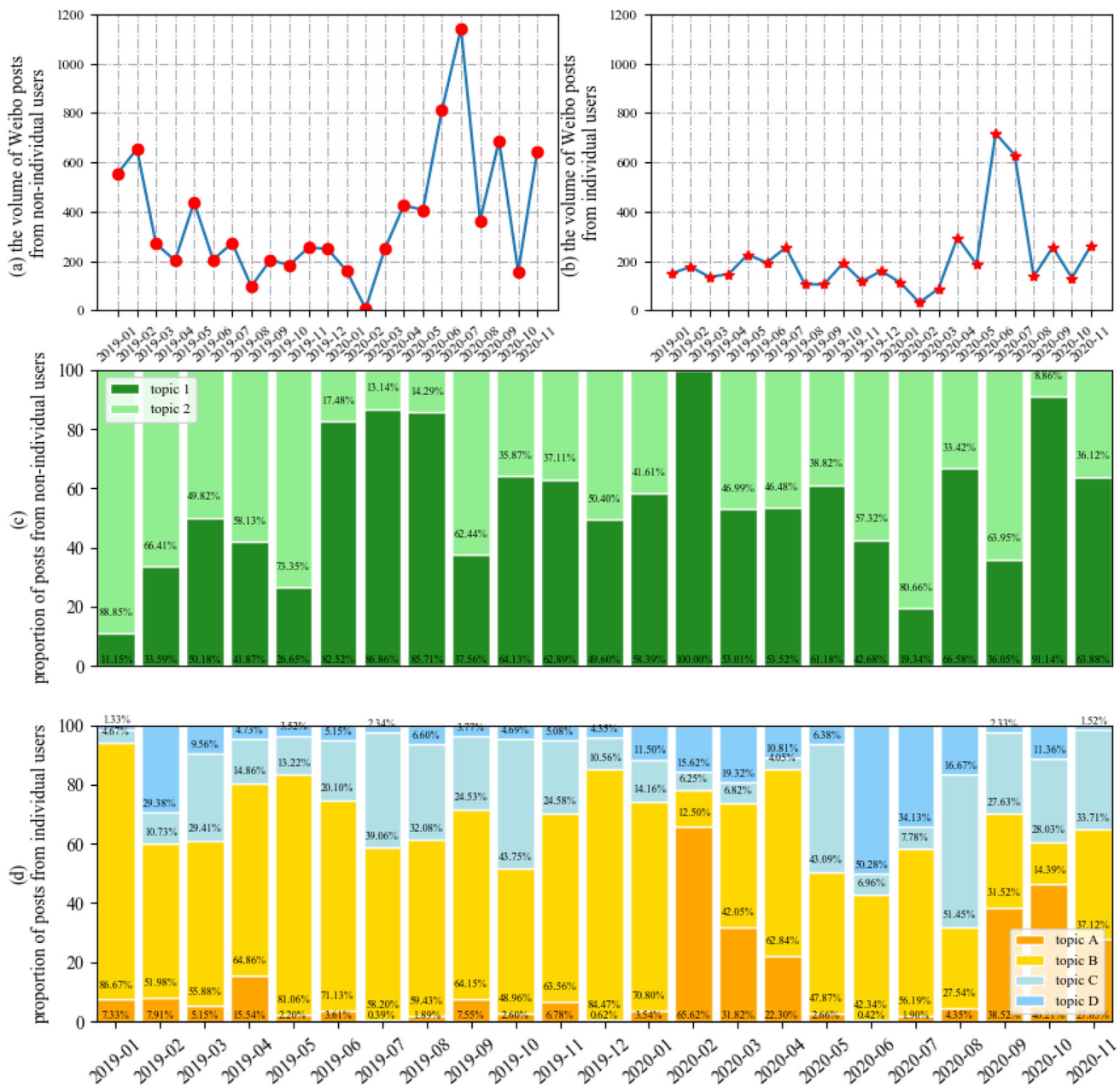


Fig. 8 Numbers of Weibo posts published by individual and non-individual users and the proportion of Weibo posts of each topic

(Topic 2). On the basis of the communication participant analysis, we can infer that non-individual users cover numerous Weibo posts of government departments' accounts. As shown in Fig. 8a and c, Weibo posts published by the accounts of government departments were relatively numerous at the beginning of 2019 when the 'zero-waste city' pilot construction policy was vigorously communicated after it was issued. The content of Topic 2 accounts for a larger proportion. The promotion of policy implementation was affected in the beginning of 2020, when the COVID-19 pandemic started. Therefore, fewer Weibo posts were published by the government, and the

proportion of promotion work was low. Only a small amount of policy interpretation information was posted. In the second half of 2020 the number of Weibo posts published by non-individual users and the proportion of policy promotion increased substantially. Moreover, the proportion of policy promotion increased again, reflecting the relative intensity of the promotion and implementation of 'zero-waste city' pilot construction policy.

For communication content, post contents published by non-individual users with government public official accounts account for a relatively high proportion. However, content topics are relatively homogeneous, mainly

aiming to strengthen the interpretation and spread of policy information, and provide references for all sectors of society on implementing and executing policies. Policy promotion activities can also be regarded as a relative reflection of policy promotion in various cities. Individual users also shared and disseminated policy information. However, the combination of policy information with daily life should be improved. Currently, such topics as the public benefits of a 'zero-waste city', celebrity commercial activities, and solid waste disposal technologies and projects mainly occur in individual users' attention rather than the content of government departments.

4 Conclusions

This paper measures the communication effect of a 'zero-waste city', a public environment policy based on policy communication theory, using text data obtained from Weibo, a social media platform. The results show the following: (1) Concerning the dynamic trend of policy communication, 'zero-waste city' policy information has been disseminated on social media constantly and widely since 2019. Particularly in the second half of 2020, the communication volume increased to a monthly average of almost 1,000, and the public attention intensified. (2) With regard to the scope of communication space, policy information communication was intense in pilot areas Shandong, Beijing, and Chongqing, whose posts exceeded more than 1,000 Weibo posts. Sichuan and Hunan have no pilot cities but pay strong attention to 'zero-waste city' work. Among the pilot cities, Xuchang of Henan Province has the highest effect of policy information communication, followed by Tongling and Shenzhen. (3) Individual, enterprise, and media accounts have a specific influence but a slightly small target audience. Charitable organisations and some NGO accounts have a weaker influence on the topic network. (4) With regard to the communication content, nonindividual accounts dominated by government public accounts have a high participation rate and content release rate in the policy communication topic network. The published contents mainly include the forwarding and interpretation of policy information, as well as policy promotion. Individual accounts share policy information and focus on solid waste disposal-related technologies and the public welfare activities of stars.

This study presents the following policy recommendations. Firstly, the amount of policy information communication and discourse influence of the public in the communication network should be improved to achieve the goal of a 'zero-waste city'. Environment departments should form a policy communication structure with a broad connection and top-bottom linkage, utilising social media and

other new channels to jointly enhance policy information communication and improve public attention and participation. Secondly, government departments should design well-considered communication strategies to interact with the public through social media in multiple policy stages, including policy formulation, implementation, and feedback phrases. Therefore, they can respond to public opinions and concerns on time and ensure the performance of the policy. Third, policy information communication can be supplemented and expanded from the 'publicness' of policies, realisation of people's livelihood interests, improvement of residents' daily life quality, and other micro perspectives. Key nodes in a communication network can be used to open a popular window through which the public can understand and accept environmental policies. Fourth, enterprises, NGOs, and other social groups should be encouraged to combine the concept of environmental protection with the concept of 'zero-waste city' in their production, operation, and consumption activities, thereby strengthening the communication of the 'zero-waste' concept.

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Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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