Construction and Trend Analysis of a Social Media Crisis Topic Evolution Model (Postprint)

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Abstract

[Purpose/Significance] Drawing on social media platforms, this study explores the dynamic classification of different stakeholders within the information lifecycle of emergency events and the evolutionary patterns of their topics of concern, thereby providing a foundation for more precise crisis information monitoring and dynamic decision-making. [Method/Process] Utilizing factual text data from specific crisis events as the source material, and guided by stakeholder theory and dynamic topic models, we construct a three-dimensional dynamic topic evolution model to conduct topic mining on the classification of different stakeholders and their topic attention in social media crisis events. This encompasses temporal granularity division, quantitative evaluation of stakeholders, identification and characterization of crisis topic viewpoints based on temporal and actor dimensions, and the utilization of visualization tools to characterize these dynamic trends. [Results/Conclusion] Based on the three-dimensional dynamic topic evolution model, the composition and classification of stakeholders exhibit significant differences across various stages, while their topics of concern and behavioral characteristics also demonstrate distinct preferences and dynamic variations. The effective integration of the dynamics of crisis actors and crisis topics can more comprehensively express the characteristics and patterns of public opinion dissemination.

Full Text

Construction and Trend Analysis of Crisis Theme Evolution Models in Social Media

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Abstract: [Purpose/Significance] Based on social media, this study explores the dynamic classification of different stakeholders during the information lifecycle of emergencies and the evolution patterns of their concerned themes, providing a basis for more precise crisis information monitoring and dynamic decision-making. [Method/Process] Using factual text data from specific crisis events as sources and guided by stakeholder theory and dynamic topic models, this study constructs a three-dimensional dynamic topic evolution model to mine the classification and topic concerns of different stakeholders in social media crisis events. This includes time granularity division, quantitative evaluation of stakeholders, identification and characterization of crisis themes based on time and subject, and visualization of these dynamic trends using visualization tools. [Result/Conclusion] Based on the three-dimensional dynamic topic evolution model, the composition and classification of stakeholders demonstrate significant differences across different stages, while their concerned themes and behavioral characteristics also exhibit distinct preferences and dynamic variations. The effective combination of crisis subject dynamics and crisis theme dynamics can more comprehensively express the characteristics and patterns of public opinion dissemination.

Keywords: stakeholders; dynamic feature classification; dynamic theme evolution; lifecycle theory **Classification Number:** G202 **DOI:** 10.13266/j.issn.0252-3116.2021.13.008

1. Introduction

In recent years, public crisis emergencies have prompted unprecedented attention from governments and emergency management departments at all levels in China to emergency response [1]. With the continuous development of technologies such as the Internet of Things and big data, researchers increasingly consider spatiotemporal dynamic characteristics and trends in emergency information management studies [2], making the real-time dynamic information needs and evolution patterns of crisis stakeholders a research hotspot [3]. Simultaneously, more users choose to express their concerns about crisis events through social media platforms, with online public opinion playing an important role in reflecting popular sentiment [4]. The hazardous and sudden nature of emergencies, combined with the freedom of internet platforms, creates different themes in emergency networks [5], greatly exacerbating the complexity and uncertainty of crisis information dissemination. This poses significant challenges to effective emergency governance and affects social harmony and stability [6]. Therefore, timely monitoring of hot topics related to emergencies on media platforms and analyzing online public opinion can reflect real public needs and holds important practical significance for public governance of emergencies [7].

Crisis information is key to crisis response and management. Comprehensive analysis of information needs helps crisis managers gain a thorough understand-

ing of event development and mobilize resources for rescue operations in a timely manner. Existing research has examined crisis stakeholders' information needs from multiple stages, dimensions, and methods. However, most studies overlook the dynamic nature of stakeholder characteristics and composition across different crisis stages.

Given this, this study re-examines the evolution process of crisis themes in social media from the perspective of dynamic stakeholder classification. First, in stakeholder identification, we consider that stakeholder classifications differ across stages and conduct a comprehensive evaluation of stakeholder classification from dimensions of relevance, influence, and attention to clarify the dynamic composition and classification changes of stakeholders at each stage. Second, based on a three-dimensional dynamic topic evolution model (multi-stage, multi-subject, dynamic needs), we analyze the evolution patterns of stakeholders' information needs under the joint influence of different stages and subjects. Finally, we conduct case verification on stakeholder classification and topic attention evolution patterns across different stages and visualize these using visualization tools.

2. Literature Review

2.1 Stakeholder Analysis in Crisis Management

Stakeholders in crisis management refer to any groups or individuals who can influence the completion of emergency response tasks and goal achievement, or who are affected by emergency response strategies [8]. Exploring different stakeholders' information concerns and their evolution trends can help crisis decision-making departments grasp the information needs of various roles and take corresponding measures [9], thereby promptly identifying extreme statements and correctly guiding online public opinion [10].

Regarding stakeholder classification in crises, researchers have proposed different methods and criteria. Through field interviews, emergency stakeholders can be divided into volunteers, public administrators, and emergency service providers [11]. Integrating multi-agent theory into emergency case knowledge base organization, earthquake stakeholders can be categorized into 10 types including government and functional departments, government rescue personnel, and disaster-affected people [12]. Additionally, emergency stakeholders can be divided into four types: the public, managers, emergency personnel, and enterprises [13]. Drawing on the "Mitchell Scoring Method," Sha Yongzhong et al. proposed a stakeholder analysis model for public crises, dividing stakeholders into core, peripheral, and potential stakeholders based on three-dimensional attributes [14]. According to these classification methods, crisis stakeholder analysis has proven helpful for crisis management in multiple application domains. For example, introducing stakeholder analysis in risk assessment can optimize decision management [15]; in flood management, stakeholder perspectives can analyze flood risk management issues [16]; for food safety emergencies, researchers divided multiple agents into 9 types and proposed four steps

for multi-agent management [17]; identifying stakeholders in nuclear waste disposal issues helps analyze risk perceptions [18]. Furthermore, researchers have noted that with the emergence of "social stakeholders," stakeholder roles are also transforming [19].

In summary, researchers have applied stakeholder theory to different types of crisis events, identifying and classifying stakeholders in emergency management from multiple perspectives. However, during different stages of crisis development, stakeholder characteristics and composition undergo dynamic changes. User classification methods based on stakeholder theory in online public opinion are dynamic, with different stakeholders convertible under certain conditions. Yet no existing research has explicitly revealed issues such as classification and identification of various subjects by stage and region.

2.2 Evolution Analysis of Crisis Information Needs and Social Platform Topic Evolution

How to adopt an effective analytical framework to identify crisis management information needs is a question requiring in-depth research in the crisis information field. First, in crisis user demand classification studies, information needs can be divided into three stages—pre-crisis, during crisis, and post-crisis—according to relevant concepts [20], or into two stages of pre-crisis and post-crisis [21]. Some researchers have also divided crisis stages according to information needs and flows in emergency management [22]. Second, researchers have conducted crisis information needs analysis in specific application domains such as climate change and disaster risk assessment in Bangladesh [23] and strategic decision-making in military organizations [24]. Finally, regarding crisis information needs analysis techniques, researchers have analyzed information needs for joint emergency activities by fire, ambulance, and police departments from an information systems perspective [25], or used data mining techniques to design business continuity information network system prototypes to monitor user information needs [26]. Other researchers have established technical analysis models to provide information bases for agencies to select communication channels and tools during post-disaster warning response phases [27].

Identifying and monitoring hot topics in online public opinion from social media sources is a popular research direction in crisis information needs evolution. Researchers have conducted co-occurrence analysis of online public opinion content to monitor theme evolution trends [28], used social network analysis methods for co-occurrence network clustering based on weighted event keywords [29], and presented emergency information monitoring in visual form [30]. Based on dynamic topic models, researchers have discretized corpora into corresponding time windows according to time series, processed them sequentially, and ultimately formed topic evolution over time [31-32]. Using Australian crisis tracking tools, researchers obtained disaster information from Twitter and Instagram for thematic analysis [33]. Additionally, methods such as trend-sensitive Latent Dirichlet Allocation [34] and unified frameworks for multi-faceted topic model-

ing [35] are commonly used to reveal topic evolution characteristics on social platforms. In public opinion monitoring, researchers have achieved topic clustering by analyzing user search content [36] and introduced user information behavior into social network public opinion topic discovery processes [37]. User emotion analysis research shows that the spread of emergencies on media platforms is driven by complex information perceptions and needs experienced by network users when facing such information, such as anxiety and doubt [38]. Furthermore, researchers have tracked user role evolution and its impact on question suggestion performance in community Q&A platforms through topic modeling [39].

In summary, existing researchers have analyzed and modeled information needs in emergency management from perspectives of different crisis management stages, multiple application domains, and various technologies. However, in different crisis stages, as stakeholders change, the information needs of various crisis management subjects also change. Research focusing on the dynamic changes of stakeholders at each stage and their information needs remains insufficient. Most existing topic evolution studies analyze topic evolution across different time periods from single time or subject dimensions, with few examining topic evolution patterns of different populations on different social media platforms from both the dynamic nature of publishing subjects and temporal dynamics.

3. Research Design

3.1 Research Approach and Process

To achieve crisis theme mining and development pattern analysis based on dynamic stakeholder classification in social media, this study takes public health emergencies as research objects. The research approach is shown in Figure 1 [Figure 1: see original paper]. First, the crisis information lifecycle is divided into different stages based on lifecycle theory. Second, stakeholders are dynamically classified based on evaluation indicator systems. Third, dynamic topic mining and development pattern analysis are conducted using the DTM (Dynamic Topic Model). Finally, the lifecycle, dynamic stakeholder classification, and dynamic topic evolution are visualized.

According to the characteristics and particularities of social media data, this study constructs a dynamic topic mining model under the combined influence of three dimensional factors: lifecycle, stakeholders, and topic mining/evolution. As shown in Figure 2 [Figure 2: see original paper], topic mining results and evolution processes dynamically change with different lifecycle stages and stakeholder types.

3.2 Construction and Analysis of the Stakeholder Dynamic Classification Topic Evolution Model

3.2.1 Lifecycle Division of Social Media Information in Public Health Emergencies Based on the characteristics of public health emergency information dissemination on social media platforms and lifecycle theory, this study divides the social media information lifecycle of public health emergencies into four stages: incubation period, outbreak period, decline period, and stabilization period, by identifying changes in information volume and landmark events.

(1) **Incubation Period:** Event characteristics are not obvious during this stage. Only a small number of users or groups pay attention to the event, making it difficult to attract focused attention from media and government departments. Information dissemination speed is slow, with relatively small amounts of related content.

(2) **Outbreak Period:** Event triggers continue to accumulate, the impact scope expands rapidly, and related information grows explosively, attracting attention from many users. The volume of information released continues to rise during this stage.

(3) **Decline Period:** This relatively long stage sees the disaster trend improving due to management emergency responses, with the attention of peripherally related public gradually decreasing.

(4) **Stabilization Period:** The event is basically under control, social order gradually restores, and only a small portion of the population remains concerned, with relatively stable fluctuations in related information volume.

3.2.2 Stakeholder Identification and Dynamic Classification Methods According to stakeholder theory and based on the public health emergency lifecycle, this study categorizes public health emergency stakeholders into four major types: medical personnel, government agencies, enterprises, and media. These four categories can be further divided into 10 subcategories including mainstream media, self-media, economic entities, and government medical institutions. Using Sina Weibo as an example, stakeholders are first classified based on username and authentication information identification—that is, by matching keywords in account usernames, authentication descriptions, work units, and profiles. After authentication identification, stakeholders undergo quantitative evaluation across different lifecycle stages (see Figure 3 [Figure 3: see original paper]). Finally, to better identify the dynamic composition and classification of stakeholders, this study calculates each stakeholder from three indicators: relevance, influence, and attention.

For relevance calculation, this study quantitatively evaluates by obtaining the number of text, images, and videos in related Weibo posts [40]. Since text, images, and videos have different weights in information dissemination, this study uses Formula (1) for calculation:

Formula (1):
$SR = SW \times 0.2 + SP \times 0.4 + SV \times 0.4$

Where SR represents the total relevance score of a specific stakeholder type in a particular stage, SW is the total text count in related Weibo posts, SP is the total image count, and SV is the total video count.

For influence indicator calculation, this study obtains follower counts and the number of forwards, comments, and likes under published Weibo posts, constructing Formula (2):

Formula (2):
$SI = SL \times 0.2 + SRE \times 0.4 + SC \times 0.4$

Where SI represents the total influence score of a specific stakeholder type in a particular stage, SL is the total like count, SRE is the total forward count, and SC is the total comment count in related Weibo posts.

Attention calculation aims to identify which stakeholder types have higher attention—that is, are more active—in specific stages. Therefore, this study uses Formula (3):

Formula (3):
$SA(i,j) = a(i,j)$

Where SA represents the total attention score of a specific stakeholder type in a particular stage, i represents the index of the 10 user subject labels, and j represents the index of the 4 crisis stages.

3.2.3 Topic Discovery and Visualization Methods for Stakeholders in Public Health Emergency Social Media First, to better acquire dynamic topics, this study adopts the DTM dynamic topic model. Traditional time series modeling mainly focuses on continuous data, while dynamic topic models are designed for categorical data. In DTM, data are divided into time slices, with each slice's documents modeled using K-Component topic models, where topics related to slice t evolve from slice t-1. Second, according to research needs, this study selects Weibo posts and user short comments as initial corpora. Considering text analysis efficiency, we summarize the viewpoints and semantics expressed in Weibo posts, establish a standardized baseline corpus after manual processing, and then use segmentation toolkits for Chinese word segmentation, stop word removal, and other natural language processing procedures to eliminate meaningless words and obtain neat, structured data for experimental corpora.

Finally, to intuitively demonstrate the dynamic classification, dissemination, and evolution processes of different stakeholders in public health emergencies on social networks, this study employs visualization tools to display evolution trends.

4. Research Results

4.1 Data Collection Results

This study used web crawler tools to collect Weibo topic data about the "Changsheng Vaccine Fraud" incident. Collected data included: Weibo post content, comment content, poster IDs, and commenter IDs. Data collection spanned from July 1, 2018, to August 30, 2018, yielding 88,647 Weibo posts. To better balance visualization effects and data variation, we selected 3-day intervals as nodes, using the sum of data within each 3-day period as the node value. Figure 4 [Figure 4: see original paper] shows the overall dissemination trend of Weibo posts and comments. Based on this trend, we divided the case's public opinion cycle into four stages: incubation period (July 1-20), outbreak period (July 21-25), decline period (July 26-August 18), and stabilization period (August 19-30).

4.2 Dynamic Composition Classification of Stakeholders and Topic Evolution Patterns

Based on the stakeholder identification algorithm, analysis results are shown in Table 1 . The sample dataset contains four major categories with 10 subcategories of stakeholders. Table 1 ranks stakeholders by total score, with the top 3 considered core stakeholders, ranks 4-7 as peripheral stakeholders, and ranks 8-10 as potential stakeholders. The table reveals that changes in stakeholder activity levels and Weibo counts across different stages lead to significant variations in their classifications.

This study conducted DTM topic extraction for different stages of the experimental corpus, obtaining 10 extracted topics for each stage and 15 related terms per topic. To more accurately mine and interpret topic semantics, we analyzed the top 5 hot topics by intensity in each dissemination cycle stage, selecting the 10 highest-probability characteristic words for topic interpretation. Hot topic characteristic word extraction results are shown in Table 2 .

Table 2: Hot Topic Extraction Results for Incubation Period Information Dissemination

Topic1	Topic2	Topic3	Topic4	Topic5
0.0807	0.1024	0.0666	0.0189	0.0744
vaccine	vaccine	biological	vaccine	vaccine
0.0496	0.0633	0.0515	0.0164	0.0450
Changsheng	Changsheng	Changsheng	Changsheng	Changsheng
0.0352	0.0386	0.0446	0.0089	0.0307
Changchun	biological	vaccine	onlooker	Changchun
0.0339 rabies	0.0266	0.0141 fraud	0.0073 fraud	0.0302
	Changchun			Shandong

Topic1	Topic2	Topic3	Topic4	Topic5
0.0204 fraud	0.0262 fraud	0.0109 trading halt	0.0067 Changchun	0.0193 DPT
0.0181 company	0.0180 incident	0.0078 company	0.0059 thorough investigation	0.0133 distribution
0.0178 record	0.0105 child	0.0075 delisting	0.0056 biological	0.0127 qualified
0.0160 biological	0.0098 Wuhan	0.0074 DPT	0.0053 Weibo	0.0122 vaccination
0.0134 rabies	0.0094 DPT	0.0071 billion yuan	0.0037 answer	0.0121 company
0.0115 involved	0.0057 vaccination	0.0069 statement	0.0035 world	0.0108 CDC

The semantic analysis of topics across emergency information lifecycle stages is shown in Figure 5 [Figure 5: see original paper]. During the incubation period, the hottest topic was the "Changsheng vaccine fraud" incident itself, with different stakeholder types expressing their views. Due to similar nature, the concurrent "Wuhan vaccine incident" was also frequently mentioned. Additionally, Changsheng Company's stock and delisting issues sparked heated discussion, becoming the third hottest topic. Weibo public opinion and subsequent vaccine distribution were also concerns.

During the outbreak period, besides the vaccine fraud incident and stock issues, detailed batches and records of the fraud began to be discussed. Relevant government agencies also started investigating, putting Changsheng's responsible persons in the spotlight. During the decline period, keywords like "officials" and "suicide" formed new hot topics, and with discussions about free vaccinations for affected victims, public sentiment gradually turned positive. During the stabilization period, discussion of the incident leveled off, with user attitudes shifting from harsh criticism to more relaxed entertainment and health topics, such as the movie "Dying to Survive."

Thus, hot topics in the incubation period were "incident reporting" and "incident discussion"; in the outbreak period, "incident investigation" and "incident emotion"; in the decline period, "incident handling" and "post-incident arrangements"; and in the stabilization period, "incident summary" and "incident-related topics."

The visualization of dynamic stakeholder composition classification and crisis theme evolution is shown in Figure 6 [Figure 6: see original paper], where different rectangles represent different categories and rectangle height represents the proportion size. The dynamic classification of stakeholders indicates different "weights" of crisis subjects across stages. Combining this weight variation trend with theme evolution trends more accurately and rapidly identifies crisis event

evolution patterns and public opinion trends while uncovering potential related patterns.

5. Discussion

5.1 Dynamic Stakeholder Classification Across Event Lifecycles Facilitates Effective Coordination and Collaboration Among Crisis Management Parties

Model verification results show significant differences in stakeholder weight scores and rankings across different crisis development stages. These differences reflect dynamic changes in attention, influence, and recognition factors that stakeholders receive during information dissemination. This variability enables managers to effectively coordinate stakeholder management strategies to maximize collaborative efficiency.

First, dynamic stakeholder composition and classification reflect the importance of crisis subjects at different stages. Table 1 shows that mainstream media consistently ranks first in weight score throughout the crisis, higher than medical departments and enterprises. This indicates that on social media platforms, user attention to media accounts exceeds that of specific institutional organizations. When medical institution accounts and media accounts publish or repost the same information, most users tend to follow the more familiar media accounts, resulting in higher forward, comment, and like counts for media accounts.

During the incubation period, economic domain stakeholders have relatively high weights, indicating that when the incident first broke, users discussed and predicted stock information trends extensively—consistent with An Lu et al.'s findings [41]. In subsequent stages, this domain's weight showed a decreasing trend, suggesting that as the situation escalated and more netizens participated, attention shifted to the incident's development itself, reducing the proportional attention to the economic domain.

Second, dynamic stakeholder composition and classification provide a basis for dynamic coordination strategies. As public crisis managers must adopt interest coordination strategies to achieve synergistic effects, different stakeholder types cannot be treated equally. Core stakeholders require high attention. For mainstream media, due to their inherent entertainment nature, they may exaggerate certain words to gain more attention. Since they hold high weight in public opinion dissemination, crisis managers should emphasize this frontline position, strengthen content review, and ensure objectivity and truthfulness to guide public opinion effectively. For lower-weight stakeholders like medical institutions, crisis managers should appropriately enhance their publicity to maximize their role in information dissemination.

5.2 Combining "Subject Dynamics" and "Theme Dynamics" in the Dynamic Topic Evolution Model Comprehensively Characterizes Crisis Event Development

The stakeholder dynamic classification crisis theme evolution model can better demonstrate event development dynamics and provide ideas for smart crisis management. The dynamic topic evolution model enhances network information analysis capabilities, monitors crisis evolution trends, and effectively guides public opinion. This model characterizes social media crisis event development from three dimensions—"theme-subject-time," deepening information aggregation theory for social media crisis events.

Based on dividing emergency event evolution cycles, this model analyzes crisis information demand characteristics, types, and content of different crisis subjects at different stages. This aligns with Cao Shujin et al.'s proposed trend of multi-mode comprehensive deep aggregation—namely, aggregation of scenario-relationship-aggregation objects [42]. Refined and in-depth research on crisis scenarios will inevitably lead to comprehensive multi-mode applications that can further satisfy the complex, diverse, and dynamic information needs of crisis subjects.

Traditional media platform crisis theme evolution research has mostly focused on information needs. This study approaches from the dynamic stakeholder classification perspective, conducting quantitative evaluation based on stakeholder theory, analyzing theme dynamics based on subject dynamics, and thereby discovering potential relationships and development patterns between the two. Theoretically, this study clarifies stakeholder characteristic classification and information demand change patterns in emergency management, proposing a three-dimensional dynamic topic evolution model. Practically, it provides a basis for dynamic coordination strategies and management in crisis management systems. Different crisis subjects cannot be treated equally—core subjects require high attention, while peripheral subjects should be actively guided to participate in public crisis assistance, providing support for real-time emergency decision-making intelligence systems.

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Author Contributions

Ma Xiaoyue: Conceptualization, research framework development;
Xue Pengzhen: Model construction, data collection;
Chen Yijin: Data analysis, manuscript writing;
Zhu Duogang: Data analysis, manuscript revision.

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Keywords: stakeholders; dynamic feature classification; dynamic theme evolution; lifecycle theory

Note: Figure translations are in progress. See original paper for figures.