Network Analysis of Emergency Information Dissemination Considering Strong and Weak Ties Between Nodes (Postprint)

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Abstract

Purpose/Significance The rapid development of new media technologies has made social media platforms the primary carriers of information dissemination. Using social network analysis to study the information dissemination structure and patterns of emergency events in the Weibo public opinion field provides theoretical support for the government to efficiently respond to emergency crises. Method/Process Taking the "Tangshan Barbecue Restaurant Assault Incident" as an example, Weibo data was collected to construct an information forwarding network with strong and weak relationships between nodes. Social network analysis was used to analyze user attributes, node attributes, network attributes, and dissemination attributes of the information forwarding network, and to explore the role patterns of strong and weak relationships between nodes in emergency event information dissemination. Results/Conclusion 1) Factors such as gender, activity level, and geographical location of network users influence user dissemination power; 2) The role of core nodes is particularly critical, as they serve as "bridges" in the dissemination chain. The dissemination of weak relationships and authoritative relationships is mainly concentrated among a few core nodes, while the dissemination paths of strong relationships are relatively dispersed; 3) The emergency event information dissemination network exhibits high dissemination efficiency and sparse characteristics; 4) Weak relationship dissemination remains dominant throughout the entire information dissemination process, with authoritative connections playing important roles at all stages of information dissemination, while the role of strong connections is mainly concentrated in the initial stage of information dissemination. The research results provide support for relevant departments in formulating effective emergency event dissemination and guidance strategies.

Full Text

Analysis of Emergency Event Information Dissemination Networks Considering Strong and Weak Relationships Between Nodes

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[**Purpose/Significance**] With the rapid development of new media technology, social media platforms have become the primary carriers of information dissemination. This study employs social network analysis to investigate the information dissemination structure and patterns of emergency events within the Weibo public opinion sphere, providing theoretical support for government agencies to effectively respond to emergency crises.

[**Methods/Process**] Taking the "Tangshan Barbecue Restaurant Assault Incident" as a case study, we collected Weibo data to construct an information forwarding network that incorporates strength relationships between nodes. Using social network analysis, we examined the user attributes, node attributes, network attributes, and dissemination attributes of this information forwarding network to explore the functional patterns of strong and weak relationships between nodes in emergency information dissemination.

[**Results/Conclusions**] (1) User gender, activity level, and geographical location influence dissemination power. (2) Core nodes play a particularly critical "bridge" role in dissemination chains, with weak and authority relationships concentrated among a few core nodes, while strong relationship pathways are more dispersed. (3) Emergency information dissemination networks exhibit high efficiency and sparse characteristics. (4) Weak relationships dominate the entire information dissemination process, authority connections play important roles at all stages, while strong connections are mainly concentrated in the initial dissemination phase. These findings provide a basis for relevant departments to formulate effective emergency event dissemination and guidance strategies.

Keywords: emergency events; information dissemination; social network analysis; Weibo; strength relationship between nodes

0 Introduction

Social media platforms have become integral components of contemporary social structure. During the occurrence and development of emergency events, the Weibo public opinion sphere has emerged as a crucial carrier for the generation and evolution of online public sentiment, serving as both an important information source and a fermentation pool. China is currently in a critical period of social transformation, where rapid modernization and the dual emergence of information and network societies are reshaping social structures while introducing greater instability and risk. Unlike traditional information control models, Weibo' s information dissemination patterns have broken the government agency-centric, unidirectional information control paradigm. In this environment characterized by multimedia interaction, coexistence of truth and rumors, and multipolar information dissemination, any emergency event can rapidly become a trending topic across the entire public opinion space. Without proper guidance, events can escalate quickly, triggering citizen anxiety and panic. Understanding the dissemination structure of emergency public opinion information on Weibo will help government agencies and relevant departments better fulfill their roles in truth-telling and opinion guidance, thereby fostering a healthy online environment and harmonious, stable social conditions.

1 Related Research

Research on emergency event information dissemination has gradually become a hot topic in academia, with scholars conducting studies from two perspectives: information dissemination patterns and network structural characteristics. Most research employs a combination of model construction and empirical analysis, primarily using social network analysis to mine key nodes and structural features of information dissemination networks on social media platforms, thereby exploring effective guidance and control strategies for emergency information dissemination.

Empirical studies have examined various cases. Shen et al. analyzed the network structural characteristics of emergency information dissemination on Weibo and WeChat during the "7·20" Henan extreme rainstorm, generating keyword propagation network topologies and calculating network density based on adjacency matrices. Wang et al. constructed an information ecology perspective model for network public opinion analysis, examining the evolution of public opinion content and sentiment using thematic and sentiment analysis during the COVID-19 Fangcabin Hospital incident. Chen et al. proposed key participants in disaster relief information networks based on stakeholder theory, quantitatively measuring variables across 19 natural disaster cases from 2016-2021. Wang established a public opinion dissemination model reflecting the changing characteristics of emergency network public opinion across different stages, analyzing the "South China Sea Arbitration" case on Sina Weibo.

Regarding network structural characteristics, Wang et al. employed stochastic Petri nets to model emergency information evolution systems, finding that such networks have small density, large average node distance, few actors, and clear small-group structures. Wang et al. measured network structural features across seven indicators from three dimensions (overall structure, position roles), using the Jiangsu Xiangshui explosion accident as a case study. Wan et al. analyzed opinion leader dissemination patterns in emergency network public opinion, examining influence through network centrality and cohesive subgroups. Wang studied financial emergency events, finding that information dissemination relies heavily on opinion leaders. Xu compared mobile and non-mobile information dissemination during the 2022 Shanghai pandemic, finding mobile dissemination faster with looser network structures.

However, current research on emergency information dissemination remains focused on dissemination patterns and often treats all individual relationships in information networks as equivalent, neglecting the significant differences in interaction strength between real-world social platform accounts and their role in information dissemination.

2 Construction of Emergency Event Information Dissemination Networks Considering Node Relationship Strength

2.1 Data Collection and Preprocessing

This study selected the "Tangshan Barbecue Restaurant Assault Incident" as a sample case. According to online public opinion monitoring platforms, by 15:00 on June 21, 2022, the incident generated 1,950,756 related public opinion items, with 1,812,569 (92.92%) on Sina Weibo. The platform hosted multiple topics with over 40 million cumulative views and more than 15 million discussions. We selected Weibo as our research platform and collected data on June 10, 2022, from the topic #PoliceReportOnTangshanBarbecueRestaurantAssaultCase#. Using web crawler programs, we gathered Weibo content, forwarding user information, and user follow lists, then performed preprocessing including deduplication and format standardization to construct a Weibo information forwarding network.

2.2 Emergency Event Information Dissemination Network Construction

From the preprocessed Weibo content, we constructed an information dissemination network for the Tangshan Barbecue Restaurant Assault Incident containing 6,819 nodes and 7,681 edges [Figure 1: see original paper]. Each node represents a Weibo user, and edges represent forwarding relationships between users. The central node is the source Weibo poster. The network exhibits a star-shaped diffusion pattern, with the most nodes directly forwarding from the source and relatively fewer secondary forwarding nodes, demonstrating strong media dissemination characteristics where information reaches users directly from mainstream accounts with minimal secondary propagation.

2.3 Classification of Node Relationship Strength

To reveal influence differences between nodes and better reflect information dissemination intensity and speed, this study classifies forwarding edges into three categories based on interaction strength: weak edges (no follow but forwarding), strong edges (mutual follow and forwarding), and authority edges (forwarding between ordinary users and mainstream media or authoritative accounts). We call this third category "authority relationships," distinct from simple strong relationships, as ordinary users are easily influenced by authoritative sources.

The classification combines forwarding relationships and follower ratios to determine relationship strength and authority. For any pair of accounts A and B with a forwarding relationship, if B forwards A' s Weibo, we first check if B follows A. If not, it' s a weak edge. If yes, we calculate the follower ratio wAB = follower count of A / follower count of B. If wAB exceeds threshold wc, we classify it as an authority edge; otherwise, it' s a strong edge.

To determine a reasonable authority threshold wc, we tested values of 1,000, 100,000, and 1,000,000. The edge type distribution is shown in [Figure 2: see original paper]. When wc increases from 1,000 to 100,000, authority edge numbers decrease significantly but stabilize. When wc reaches 1,000,000, authority edges drop sharply, likely because the threshold is too high, excluding many one-way follow relationships. We selected wc = 10,000 as the authority edge threshold, where authority edge quantities are stable. At this threshold, weak edges dominate the network (consistent with literature showing weak relationships prevail in Weibo dissemination), while strong edges are least numerous, likely representing close relationships like friends or family, or interactions between influential opinion leaders and mainstream media.

3 Results Analysis

3.1 User Attributes

3.1.1 Gender Distribution Female users significantly outnumber males in information dissemination [FIGURE:3(a)]. [FIGURE:3(b) shows edge type distribution by gender, revealing that female users' authority and weak edge proportions closely match the overall network distribution, indicating their substantial influence in information dissemination.

3.1.2 Follower and Following Count Distribution User following and follower count distributions are shown in [Figure 4: see original paper] (with logarithmic transformation for better visualization). Analysis reveals: (1) Concentrated distribution: most users follow 100-1,000 accounts (log10 2.0-3.0) and have 10-500 followers (log10 1.5-2.5), reflecting typical social media activity patterns. (2) Outliers: a few users have over 10,000 followings or followers (log10 4.0), representing particularly active or influential users (celebrities, mainstream media) who play key roles. (3) Left-skewed follower distribution: most users have relatively few followers, with a small number having extremely high follower counts.

3.1.3 Geographic Distribution Information dissemination participants concentrate in Guangdong, Sichuan, and Shanghai [Figure 5: see original paper]. These economically developed provinces lead in network penetration and user activity, resulting in higher participation. Guangdong shows the highest user count, suggesting economically advanced regions are more susceptible to emergency events and have stronger information dissemination power.

3.2 Node Attributes

3.2.1 Node Centrality We used degree centrality to identify key nodes, measuring a node' s importance by its direct connections [20]. In this context, it represents the number of times a user forwarded information or was forwarded. Table 1 lists the four most central nodes in the Tangshan incident network, all of which forwarded information shortly after the event, demonstrating the critical role of early forwarding.

The centrality distribution across different edge types [Figure 6: see original paper] shows that strong-edge nodes generally have higher centrality, occupying central positions in the network and primarily consisting of opinion leaders and mainstream media. Weak and authority edges involve many ordinary users, resulting in lower centrality.

3.2.2 Node Degree Distribution Degree distribution reveals the probability distribution of edges per node [21], helping identify whether networks have highly centralized core nodes or dispersed pathways. The overall degree distribution and type-specific distributions are shown in [Figure 7: see original paper]. Most nodes have low degrees, acting as information recipients rather than disseminators. However, some high-degree nodes exist—authoritative sources or users with extensive social connections—demonstrating strong dissemination capabilities.

Comparing edge types, weak and authority edges show relatively concentrated degree distributions, indicating their dissemination concentrates among few core nodes. Strong edges show more dispersed distribution, suggesting strong-relationship pathways are more distributed.

3.3 Network Attributes

3.3.1 Average Path Length Average path length measures the mean distance (number of edges) between any two nodes [22]. The Tangshan incident network has an average path length of 2.012, indicating high efficiency—information can spread between nodes in approximately two steps. Weak and authority edges show relatively concentrated degree-degree correlations, suggesting their dissemination is concentrated among core nodes with smaller degree differences. Strong edges show more dispersed distribution.

3.3.2 Network Diameter Network diameter is the maximum shortest path length between any node pair, measuring network scale and dissemination speed [22]. The network diameter is 4, reflecting high compactness—information can spread across the network quickly.

3.3.3 Network Density Network density measures connection tightness, defined as actual connections divided by possible maximum connections. The network density is 0.000311, indicating sparse connections between nodes.

3.3.4 Network Clustering Coefficient The clustering coefficient measures neighbor connectivity, defined as the ratio of actual to possible edges among a node' s neighbors, averaged across all nodes [22]. The network clustering coefficient is 0.061, also indicating loose connections.

Degree-degree correlation measures the relationship between a node' s degree and its neighbors' degrees [21]. The Pearson correlation coefficient r is -0.883, showing that high-degree users tend to connect with low-degree users—a common phenomenon where influential users disseminate information to the masses, while ordinary users participate by forwarding or commenting.

3.4 Dissemination Attributes

3.4.1 Dissemination Depth Analysis Dissemination depth measures the hops from source to specific nodes [23]. In Weibo forwarding networks, depth-1 represents direct forwarding from the source, while depth-2 represents indirect forwarding through first-level users. [Figure 8: see original paper] shows that authority and strong edges mainly exist at depth-1, playing crucial roles in initial dissemination. At depth-2, weak edges dominate, indicating that once information spreads from core users, it rapidly diffuses through weak connections across the network—a finding consistent with the theory emphasizing weak ties' importance in information bridging.

3.4.2 Dissemination Stage Analysis The information dissemination process can be divided into four stages: incubation, climax, mitigation, and decline [24,25]. [Figure 9: see original paper] shows forwarding volume over time. The source Weibo was posted on June 10, 2022, about #PoliceReportOnTangshanBarbecueRestaurantAssaultCase#. Information quickly peaked, then gradually declined.

[Figure 10: see original paper] shows edge type distribution across stages. During the climax stage, authority edges account for 15.4%, strong edges 7.5%, and weak edges 77.0%. During mitigation, authority edges rise to 44.9%, strong edges drop to 2.1%, and weak edges decrease to 53.0%, indicating stabilization where familiar relationships and authorities play important roles. During decline, authority edges drop to 33.0%, strong edges remain at 2.1%, and weak edges rise to 64.8%, showing reduced authority influence and a return to familiar weak relationships.

4 Conclusions and Implications

4.1 Conclusions

Based on the Tangshan Barbecue Restaurant Assault Incident, we constructed an emergency event information dissemination network considering node relationship strength, analyzing user attributes, node attributes, network attributes, and dissemination attributes. Key findings include:

User attribute analysis reveals that female users, highly active or influential users, and users from economically developed provinces have stronger dissemination power. Node attribute analysis shows that nodes connected by strong relationships generally occupy central positions, likely comprising opinion leaders and mainstream media. Weak and authority relationship pathways concentrate among few core nodes, while strong relationship pathways are more dispersed. Network attribute analysis indicates the emergency information dissemination network has high efficiency and sparse characteristics. Dissemination attribute analysis demonstrates that weak relationships dominate throughout the process, authority connections play important roles at all stages, while strong connections are mainly concentrated in the initial dissemination phase.

4.2 Implications

These results deepen understanding of emergency information dissemination patterns and offer insights for managing agricultural emergency information dissemination:

Regarding user attributes, focus on active network users (female users, economically developed region users, influential opinion leaders) and develop targeted guidance strategies based on their information needs. For node attributes, monitor and guide core nodes (public figures, mainstream media) in real-time to prevent inaccurate or misleading information, and emphasize interactions between mainstream agricultural media accounts that rapidly expand dissemination scope. For network attributes, leverage social media’ s powerful dissemination capabilities by releasing official information early to guide public opinion and prevent misinformation. For dissemination attributes, emphasize the dominant role of authority connections through government agencies and mainstream media for effective information release and verification, particularly during initial stages. Monitor and guide key nodes to manage dissemination direction and speed more effectively.

Limitations include incomplete user attribute crawling and insufficient methodological diversity. Future research will enrich user characteristics (age, occupation, education) through interviews or questionnaires and introduce methods like machine learning and graph neural networks to predict dissemination paths and node relationships, thereby improving comprehensiveness and effectiveness.

References

[1] HOU L J, ZHANG F. Information dissemination mechanism and countermeasures of micro-blog negative public opinion [J]. Mathematics in practice and theory, 2018, 48(23): 167-174.

[2] WANG H. The characteristics and guiding strategies of microblog public opinion field[J]. Youth journalist, 2023(19): 60-62.

[3] CHEN R. Research on the evolution and influence of media users communication power from the perspective of media change [D]. Kunming: Yunnan Normal University, 2023.

[4] FANG X, HUO L A, HUANG P Q. An interaction model for official information and unconfirmed information after emergencies[J]. Journal of systems & management, 2018, 27(4): 722-728.

[5] LI W L, GAO G H. An analysis of the research progress and trends of emergency network public opinion[J]. Journal of Chongqing university of posts and telecommunications (social science edition), 2019, 31(5): 60-68.

[6] YANG Z W, LIU D L. Research progress of emergency network public opinion in China[J]. Henan science, 2023, 41(1): 108-116.

[7] WANG L, ZHANG M X, WU J. Propagation and evolution of public opinion in the outbreak of COVID-19 from the perspective of information ecology[J]. Information science, 2022, 40(1): 31-37, 50.

[8] GE Y. Strengthen the social risk assessment and governance of major decision-making[J]. China management informationization, 2023, 26(17): 193-196.

[9] CHEN Y X, SU Z W, ZHOU L. Key factors and effective path of disaster relief information network dissemination[J]. Journal of intelligence, 2022, 41(5): 106-111.

[10] WAN Y J, LI S Y, FANG Z H, et al. Dissemination influence of Internet public opinion leaders in emergencies based on SNA [J]. Journal of Xi' an university of science and technology, 2022, 42(2): 290-298.

[11] WANG X W, XING Y F, WANG N A X, et al. An empirical study on information dissemination of network public opinion on emergencies under the new media environment[J]. Information studies: Theory & application, 2017, 40(9): 1-7.

[12] WANG X Q. Research on the characteristics and laws of financial public opinion events[J]. Information science, 2021, 39(4): 54-61.

[13] WANG Z Y, LI Y J, WANG W K. Evolving model of information towards emergencies based on stochastic petri net[J]. Chinese journal of management science, 2020, 28(3): 113-121.

[14] XU J S, QI K. Research on microblog network community mining and

characteristics of public health emergencies: Based on the analysis of the 2022 Shanghai epidemic event[J]. Information research, 2023(11): 74-80.

[15] DENG J G, ZHANG X, FU Z, et al. Research on network public opinion propagation of emergencies based on system dynamics: Taking "Xiangshui explosion accident in Jiangsu" as an example[J]. Data analysis and knowledge discovery, 2020, 4(S1): 110-121.

[16] XIANG Z J. The influence of strong and weak relationship on the information dissemination of emergencies[J]. Youth journalist, 2020(35): 18-19.

[17] SHEN J H, WANG C L, PAN J L, et al. Comparison of keyword topology networks of microblog and WeChat emergency information based on SNA: Case study of "7 • 20" extraordinary rainstorm in Henan[J]. Information research, 2022(8): 69-78.

[18] LI D D, MA J. Rumor spreading and controlling strategies research in social networks[J]. Journal of systems & management, 2017, 26(5): 835-841.

[19] WANG J, CHEN F P. Analysis of structural features of public opinion dissemination network for emergency events based on SNA - Take Jiangsu Xiangshui "3.21 explosive accident" as an example[J]. Journal of university of electronic science and technology of China (social sciences edition), 2021, 23(1): 10-18.

[20] LI F, WEI Y. Simulation analysis of viral-style information diffusion in small world networks[J]. Journal of system simulation, 2019, 31(9): 1790-1801.

[21] XIA Y X. Research on modeling and prediction of network topic dissemination law[J]. Journal of modern information, 2019, 39(4): 3-12.

[22] QIAO Y W, ZHONG Z J, XU X K, et al. Emotional polarity and contagion pattern in unexpected public opinion: From the perspective of network analysis[J]. Journal of Jishou university (social sciences), 2021, 42(6): 131-142.

[23] LAN Y X, XIA Y X, LIU B Y, et al. The research on propagation phase accurate model and simulation of network public opinion [J]. Journal of modern information, 2018, 38(1): 76-86.

[24] XU X K, HU H B, ZHANG L, et al. Computational communication on social networks[M]. Beijing: Higher Education Press, 2015.

[25] SUN X J, SI S K. Complex network algorithms and applications[M]. Beijing: National Defense Industry Press, 2015.

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