

Postprint: Dynamic Evolution of Major Emergencies Based on Event Logic Graphs

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Abstract

[Purpose/Significance] To respond to major emergencies more rapidly and efficiently, this study investigates the dynamic evolution process of major emergencies, aiming to assist relevant departments in emergency response and decision-making. [Method/Process] Based on the theory and methodology of event logic graphs, an abstract event logic graph for major emergencies is constructed through steps including graph construction and event generalization. The driving factors of event evolution are further analyzed and summarized, and dynamic simulation of event evolution is conducted by integrating system dynamics models. [Results/Conclusion] The research findings demonstrate that highly generalized knowledge can reveal the causes and influencing factors of event evolution; the combination of major emergency event logic graphs and system dynamics methods enables simulation of the event evolution process from a knowledge perspective.

Full Text

Research on the Dynamic Evolution of Major Emergencies Based on Event Knowledge Graph

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Abstract:

[Purpose/Significance] To respond to major emergencies more rapidly and efficiently, this study investigates the dynamic evolution process of major emergencies, aiming to assist relevant departments in emergency response and decision-

making. [Method/Process] Based on the theory and methodology of event knowledge graphs, this research constructs an abstract event knowledge graph for major emergencies through event knowledge graph construction and event generalization. It further analyzes and summarizes the drivers of event evolution, and conducts dynamic simulation of event evolution using a system dynamics model. [Result/Conclusion] The findings demonstrate that highly generalized knowledge can reveal the causes and influencing factors of event evolution. The integration of major emergency event knowledge graphs with system dynamics methods enables simulation of event evolution processes from a knowledge perspective.

Keywords: major emergencies; event knowledge graph; event motivation; simulation analysis

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Major emergencies pose severe threats to social stability and the safety of people's lives and property in China. Emergency management of major emergencies has become a top priority in national emergency system construction. The evolution of major emergencies represents the essential and core issue in emergency management; therefore, revealing the evolution process and summarizing the evolution patterns of major emergencies is of great significance. This paper employs event knowledge graph theory and methods to process massive unstructured textual data and information through information extraction and fusion techniques, presenting them structurally in graph form to mine the logical relationships of major emergencies. Based on this foundation, it simulates the dynamic evolution process of major emergencies to reveal evolution patterns and modes, providing practical evidence for major emergency governance [1].

2 Research Status

2.1 Domestic Research Hotspots on Emergency Evolution

Using CNKI as the retrieval platform with the themes “emergency + evolution” and “emergency + evolution,” and after removing duplicates and irrelevant literature, a total of 1,402 documents were retrieved. Analyzing the co-occurrence of high-frequency keywords in these documents reveals research hotspots in domestic major emergency evolution mechanism studies, as shown in Figure 1 [Figure 1: see original paper]. The figure indicates that research hotspots primarily focus on online public opinion, evolution mechanisms, emergency management, and emergency decision-making. The evolution of online public opinion in major emergencies includes emotional evolution and topic evolution. Regarding emotional evolution, Zhang Haitao et al. [2] selected the COVID-19 public health emergency as their data source, using literature review, Delphi method, and fuzzy set theory-DEMATEL model to identify influencing factors of user emotional evolution. In evolution mechanism research, Chen Jinghao et al. [3] utilized survival analysis to study the lifecycle and influencing factors of online

public opinion in 70 major social security events. Yao Leye et al. [4] applied Lasswell's "5W" communication model to construct a framework for public opinion evolution elements in major natural disasters. In scenario evolution, Xu Di [5] proposed a scenario-based emergency event chain construction method, while Liu Dehai et al. [6] combined evolutionary game theory with infectious disease SI models to study pandemic transmission under different scenarios.

2.2 International Research Hotspots on Emergency Evolution

Using the Web of Science Core Collection as the retrieval database with the keywords "emergency" + "evolution," and excluding irrelevant literature, 709 English documents were retrieved. Visual analysis and keyword frequency statistics revealed international research hotspots on major emergency evolution. Analysis shows that international scholars have produced abundant research on early warning and risk assessment, modeling and technology, emergency management, and decision-making for major emergencies, though studies on evolution mechanisms remain relatively scarce. In modeling and technology, D.K. Allen et al. [7] addressed key technical and organizational issues in information sharing during major emergencies. M. Imran et al. [8] provided methods for extracting situational awareness elements from social media. In emergency management and decision-making, K. Yu et al. [9] proposed a stepwise ontology construction method for emergency response. In evolution research, D. Brennan et al. [10] analyzed SARS evolution mechanisms, while A. Sagun et al. [11] used simulation technology to model crowd behavior patterns, and S. Shan et al. [12] analyzed knowledge's role in emergency evolution through structural equation modeling.

2.3 Event Knowledge Graph-Based Research on Major Emergencies

Since 2021, increasing research teams have applied event knowledge graphs to emergency studies. Li Gang et al. [13] proposed a national security event graph model. Zhang Haitao et al. [14] constructed a cognitive framework for major emergency evolution mechanisms, and built event knowledge graphs for COVID-19 through ontology construction, event extraction, and relationship extraction [15]. They also developed a situational awareness model based on data-knowledge dual drive [16]. Sun Xinrui et al. [17] constructed traffic knowledge graphs for event identification. Hu Huan [18] built causal event knowledge graphs for hot topics. Liu Zhongbao et al. [19] developed historical event extraction methods for "Records of the Grand Historian."

Based on this literature review, research on major emergency evolution shows diversified directions and advanced methods, but studies on evolution processes and mechanisms remain limited, lacking a complete theoretical and methodological system. This paper employs event knowledge graph methods to mine evolution drivers and combines system dynamics to simulate dynamic evolution under different scenarios, aiming to reveal evolution mechanisms and provide practical evidence for emergency response.

3 Dynamic Evolution of Major Emergencies Based on Event Knowledge Graph

3.1 Construction of Major Emergency Event Knowledge Graph

The construction process, based on our team's previous research, includes three main components: text data processing, event extraction, and inter-event relationship extraction. Data sources primarily include China News Service, WHO website, and The Lancet regarding COVID-19, totaling 13,378 documents collected using Python. The BERT+BILSTM+CRF model identified event elements, while pattern matching and a domain causal relationship template library extracted relationships. This yielded 14,252 event relationships (13,019 causal, 820 conditional, and 413 sequential), constructing a public health emergency knowledge graph containing 14,413 events and 14,252 edges [18], as shown in Figure 3 [Figure 3: see original paper].

3.2 Construction of Abstract Event Knowledge Graph

Compared to specific event knowledge graphs, abstract event knowledge graphs reveal more essential and regular knowledge. This requires generalizing specific events into abstract events. For instance, reports like "COVID-19 outbreak in X region causes economic slowdown" can be generalized to "pandemic causes economic slowdown." This generalization process condenses event knowledge and represents evolution patterns with significant practical application value for emergency management decision-making.

3.2.1 Event Generalization Event generalization is the foundation and core of abstract knowledge graph construction, and a key factor determining its quality. This study uses BERT-wwm-ext to vectorize events and K-Means++ for clustering. After generalization, nine event categories were obtained: epidemic source (1,609 events), pandemic (2,258), information dissemination (2,191), medical care (828), pathogen (2,312), disease (1,277), transmission (689), economy (1,541), and politics (1,708). Partial results are shown in Table 1 .

3.2.2 Abstract Event Knowledge Graph Based on the generalization method, specific events were abstracted. After manual screening and node expansion, the abstract structure of the COVID-19 event knowledge graph was formed, as shown in Figure 4 [Figure 4: see original paper]. Nodes represent generalized events, edges represent relationships, with directed edges connecting cause and effect events.

3.2.3 Analysis of Event Evolution Drivers Based on the abstract knowledge graph, the drivers of COVID-19 evolution can be summarized, as shown in Figure 5 [Figure 5: see original paper]. The main driving paths include: epidemic source → pathogen → disease → transmission → pandemic → information dissemination → medical care → disease → transmission → pandemic;

and similar paths involving economic and political factors. Pandemic and public opinion are critical nodes controlling evolution, as public opinion can form new derivative feedback loops with economic and political factors. Overall, COVID-19 evolution is driven by dual paths: the physical transmission path (epidemic source, pathogen, disease transmission) and the information dissemination path, with overlapping events between them. Medical, economic, political, and public opinion factors directly or indirectly determine the evolution direction. Understanding these drivers enables targeted management for maximum decision-making effectiveness.

4 Dynamic Evolution Analysis of Major Emergencies

4.1 Construction of Dynamic Evolution Flow Diagram

Major emergency evolution is a complex process with numerous influencing factors forming multi-layered causal relationships and multiple feedback loops—a nonlinear system suitable for system dynamics modeling. This study uses system dynamics to simulate COVID-19 evolution, combining causal relationships from the abstract knowledge graph to reproduce system structure and dynamic behavior patterns. The model includes 14 variables: 6 level variables (medical resource investment, economy, natural/social resources, pandemic, consumption 1, consumption 2), 4 rate variables (medical consumption, livelihood demand, production, evolution), and 4 constants (medical policy, economic policy, disease transmission, disinformation spread). The dynamics flow diagram is shown in Figure 6 [Figure 6: see original paper].

4.2 Simulation Result Analysis

Using the AnyLogic platform and historical data from the National Health Commission, the model parameters were estimated. Three representative scenarios were simulated:

4.2.1 No Intervention Scenario With medical policy parameter set to 0, the simulation (Figure 7 [Figure 7: see original paper]) shows that without medical intervention, medical resources continuously decline while pandemic indicators keep rising, indicating sustained spread, while economic indicators continuously decrease. This demonstrates that without medical policy intervention, continuous pandemic spread leads to collapse of both the medical system and social economy.

4.2.2 Medical Intervention Only Scenario With medical policy parameters set to 0.15 and 0.6 (Figures 8 [Figure 8: see original paper] and 9 [Figure 9: see original paper]), increased medical investment initially raises pandemic indicators before they decline, while the economy decreases with pandemic diffusion. Medical policy intervention affects pandemic trends and suppresses development to some extent. However, when medical funding increases from 0.15

to 0.6, pandemic indicators 反而 rise, indicating that larger medical investment does not necessarily improve control. The evolution process involves complex interactions requiring systematic analysis to find optimal allocation.

4.2.3 Medical and Economic Dual Intervention Scenario With medical policy at 0.15 and economic policy at 0.5 (Figure 10 [Figure 10: see original paper]), when both medical investment and economic growth are sustained, pandemic indicators rise to a critical point then continuously decline, indicating gradual control until elimination. This shows that for COVID-19, dual intervention requires finding the balance point between investment and allocation for optimal control in the shortest time.

These three scenario simulations enable pandemic trend prediction. This knowledge-driven approach, combining event logic mining with system dynamics simulation, achieves the goal of revealing evolution patterns from a knowledge perspective, providing scientific evidence for decision-makers [20].

Conclusion

This study constructed a COVID-19 event knowledge graph, mined deep logical relationships, and obtained highly generalized knowledge to reveal evolution causes and influencing factors from a knowledge-driven perspective. By combining causal relationship analysis from the abstract knowledge graph with system dynamics theory, the dynamic evolution process was simulated. This integration breaks through traditional statistical analysis paradigms, enabling knowledge-driven simulation of event evolution, which is significant for understanding evolution patterns and achieving precise governance.

Limitations include data constraints and lack of detailed analysis of other emergency types. Future research will optimize knowledge graph construction processes, improve generalization precision and accuracy, and scientifically mine evolution patterns.

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Author Contributions:

Liu Yashu: Data collection, analysis, and initial manuscript writing;
Luan Yu: Data analysis and manuscript revision;
Zhou Honglei: Data collection and organization;
Zhang Haitao: Research design and methodology.

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

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