# Postprint: Research on the Construction of a "3$\times$3" Emergency Intelligence System from an Information Ecology Perspective

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## Abstract

[Purpose/Significance] From the perspective of balancing information ecology elements, this study constructs an emergency intelligence system, innovatively proposing an emergency intelligence system capable of fundamentally addressing crises and achieving sustainable service and management, thereby promoting the formation of a public health emergency intelligence system in China that integrates "dynamic and static elements" and combines "peacetime and wartime" approaches. [Method/Process] The literature research method is employed to summarize the current research status of emergency intelligence systems at home and abroad, and to analyze the reference value of information ecology theory for the construction of emergency intelligence systems. From the information ecology perspective, this paper analyzes the phenomenon of information ecology imbalance in the context of public health emergencies, and constructs an emergency intelligence system model based on the three-layer ecological structure of information environment layer, technical platform layer, and information decision-making layer, which integrates both "dynamic emergency management flow" and "static ecological balance flow" on the basis of traditional intelligence flow. [Results/Conclusion] From the information ecology perspective, a "3$\times$3" emergency intelligence system that combines "dynamic and static integration" with "peacetime-wartime integration" is proposed, constructing an emergency intelligence system conducive to improving the information ecology environment, balancing the dynamic relationships among information actors, information technology, information systems, and the information environment, and reserving risk prevention and control capability, sharing and openness capability, analysis and decision-making capability, and resource scheduling capability for emergency intelligence response work.

# Full Text

## Preamble

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## Research on the Construction of a "3$×$3" Emergency Intelligence System from the Perspective of Information Ecology

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**Abstract:** [**Purpose/Significance**] This study constructs an emergency intelligence system from the perspective of information ecology element balance, innovatively proposing a system capable of fundamentally addressing crises while achieving sustainable service and management. This work promotes the development of a public health emergency intelligence system in China that integrates both "dynamic and static states" and combines "peacetime and wartime" operations. [**Method/Process**] Through literature review, this paper summarizes the current research status of emergency intelligence systems both domestically and internationally, and analyzes the referential value of information ecology theory for emergency intelligence system construction. From the information ecology perspective, it examines information ecological imbalance phenomena in the context of public health emergencies and proposes an emergency intelligence system model based on a three-layer ecological structure—comprising an information environment layer, technical platform layer, and information decision-making layer—while incorporating both "dynamic emergency management flow" and "static ecological balance flow" alongside traditional intelligence workflows. [**Result/Conclusion**] The study proposes a "dynamic-static combination" and "peacetime-war combination" "3$×$3" emergency intelligence system from the information ecology perspective. This system improves the information ecological environment, balances the dynamic relationships among information actors, information technology, information systems, and the information environment, and cultivates capabilities in risk prevention and control, data sharing and openness, analytical decision-making, and resource scheduling for emergency intelligence response.

**Keywords:** information ecology theory; public health emergencies; emergency intelligence system
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In recent years, China has made significant progress in constructing emergency intelligence systems for public health emergencies. Intelligence systems centered on collection, processing, analysis, and decision-making have formed a comprehensive "intelligence mega-system" covering all of society. Whether local and departmental emergency intelligence command centers or China's infectious disease and public health emergency direct reporting network, these systems play crucial roles as "eyes and ears," "vanguards," and "advisors" in responding to public health emergencies. Traditional emergency intelligence systems emphasizing intelligence service flows and organization-oriented collaboration exhibit professionalism and timeliness. However, against the backdrop of complex and uncertain public health emergencies, intelligence emergency response requires building and perfecting a system with sustainable response capabilities. Therefore, to enhance the response capacity for public health emergencies, this study attempts to analyze information ecological imbalance phenomena in the public health domain and construct a "3$×$3" emergency intelligence system that combines "dynamic and static states" and integrates "peacetime and wartime" operations, forming an intelligence flow business layer centered on technical platforms, a static ecological balance flow based on the information environment, and a dynamic emergency management flow centered on information decision-making.

## 2 Information Ecology Theory and Emergency Intelligence System

Based on systematic review and in-depth analysis of diverse research on emergency intelligence systems in the intelligence science field, this paper selects a new perspective based on information ecology theory to analyze emergency intelligence service systems, demonstrating the scientific feasibility of this approach.

### 2.1 Diverse Research Perspectives on Emergency Intelligence Systems in Intelligence Science

Current domestic research on emergency intelligence systems primarily focuses on perspectives such as intelligence lifecycle, overall architecture theory, crowdsourcing models, integration models, and collaborative governance models. Zeng Ziming and Huang Chengying [1] constructed an emergency intelligence system centered on public health data based on intelligence needs at different stages of public health emergencies. Yang Qiaoyun [2] advocated for the concept of "reverse fragmentation" and "anti-fragmentation," providing collaborative emergency governance ideas from a holistic perspective. Fan Bo and Liu Ruoxuan [3] further analyzed cross-departmental intelligence linkage systems based on supply chain theory within a collaborative governance framework. Gong Yiwei et al. [4] introduced crowdsourcing models to propose an emergency management model and intelligence system integrating crowdsourcing. Su Xinning et al. [5] constructed an emergency intelligence system model using lifecycle theory and methods. Yang Feng and Yao Leye [6] integrated comprehensive integration thinking to analyze the framework of rapid response intelligence systems with knowledge, machine, and expert systems as cores. Yuan Li et al. [7] constructed a rapid response intelligence system for emergency decision-making from a top-level perspective based on Enterprise Architecture (EA) theory.

International scholars have also conducted extensive research on emergency intelligence systems, primarily focusing on decision support for crisis events, platform systems, collaborative processes, and knowledge bases, with less emphasis on theoretical methodological construction. A. Fertier et al. [8] designed an emergency decision support system based on event-driven and multi-source dynamic data, connecting emergency managers with multiple data sources specifically for crisis decision-making. A.M. Barthé-Delanoë et al. [9] proposed that intelligence work strongly depends on inter-organizational collaborative processes and corresponding workflows. N. Oh [10] compared response systems for Hurricane Katrina and Hurricane Gustav, suggesting that building a common knowledge base can effectively upgrade emergency system interaction capabilities. O. Ajao et al. [11] studied improved algorithms for Twitter-based social network services as early warning systems for emergencies. H. Guo et al. [12] constructed an emergency intelligence system based on macro, meso, and micro-level interrelated symbiosis theory, elaborating on the compositional relationships between system levels and interactions among elements.

In summary, existing research either adopts a systems engineering perspective focusing on intelligence lifecycle with prominent practical characteristics of process standardization, or approaches from a systems practice perspective emphasizing crowdsourcing, integration, and collaborative governance models, using multi-agent participation and relationships among intelligence actors as entry points. While these studies clarify critical aspects such as intelligence collection, analysis, and decision-making, they rarely consider communication and interaction among elements within intelligence business processes, lack perception of dynamic changes in internal and external environments, treat emergency events as short-term problems to respond to, and fail to optimize the environment from a sustainable development perspective to reduce negative impacts of emergencies. This paper argues that emergency intelligence system research should emphasize both "wartime" crisis early warning and peacetime early warning capability reserves, improving information system utilization efficiency by enhancing intelligence personnel quality and dynamically perceiving external environmental changes, thereby continuously optimizing and improving the information ecology.

### 2.2 A New Perspective Based on Information Ecology Theory

Information ecology theory originates from the concept of information ecology proposed by Academician Zhang Xinshi [13], who stated that information ecology not only possesses the advantages of high technology and information theory from information science but also inherits and develops traditional ecological theories, emphasizing comprehensive analysis, simulation, and prediction of issues related to human, ecosystem, and biosphere survival. Domestic scholars have conducted multi-perspective, diversified, and multi-level research on information ecology theory. Some scholars focus on information ecology components. For instance, Hu Yunqing [14], Lü Guifen [15], Wang Wei et al. [16], Meng Ruiling [17], and Tian Chunhu [18] all believe that information ecology constitutes the sum of relationships among information, people, and the information environment. Other scholars emphasize that information ecology centers on information actors within the information environment. Zhu Menggang et al. [19] noted that information ecology systems reconsider information management from a human perspective, with human activities occupying a core position under certain technical support. Some scholars also study information ecology from the perspective of information circulation and element interaction. Li Zhichang [20] pointed out that an information ecosystem is an organic whole composed of information environmental elements and their interrelationships that realize social information functions, where various elements influence and promote each other.

In summary, domestic scholars' research on information ecosystems is comprehensive with different emphases, though most approaches focus on definitions, element composition, element systems, and interactions, remaining largely at the theoretical level. Research results often involve the conceptual scope of the information ecological environment but fail to address practical information ecosystem problems from the perspective of internal interaction results and functions. This paper argues that with the continuous maturation and rapid development of Internet and big data technologies, information systems will become important carriers and components of information ecosystems. Therefore, this study will analyze from the perspective of four elements in information ecosystems—information actors, information technology, information systems, and the information environment—and their interrelationships. The composition elements of an information ecosystem are shown in Figure 1 [Figure 1: see original paper].

### 2.3 Applicability of Information Ecology Theory to Emergency Intelligence System Research

Originating from ecology, information ecology theory primarily studies the relationship between humans and the information environment. In the context of public health emergencies, phenomena such as information overload, information monopoly, information noise, and pollution frequently occur. This paper argues that information ecology theory offers referential significance for constructing emergency intelligence systems in public health emergencies, mainly manifested in: strengthening crisis capture and external environment perception through harmonious balance concepts; optimizing intelligence full-process transmission and response through holistic value concepts; preparing daily databases, algorithm libraries, and technology libraries through dynamic repair concepts to achieve stable information niches and sustainable optimization of the information environment; and improving the static closure and lack of external communication in emergency intelligence systems through competitive and open concepts.

From the information ecology factor perspective, both information ecology and emergency intelligence systems are systems formed based on interactions among information actors, information systems, information technology, and the information environment, sharing identical elements. Applying information ecology's harmonious balance concept enables perception and capture of information ecology factors, providing dynamic intelligence sources and daily crisis factor reserves for emergency intelligence systems. From the information ecology chain perspective, emergency intelligence systems need to draw on holistic value concepts, constructing from the perspective of maintaining complete emergency intelligence processes to achieve information creation, transmission, and consumption on the information ecology chain, helping emergency intelligence personnel obtain cognition, changes, and trends of public health emergencies from an overall process perspective. Therefore, from the information ecology chain perspective, this approach not only avoids neglecting source problems in traditional emergency theories but also enhances emergency response and crisis early warning capabilities through processes and links. From the information ecosystem perspective, information ecosystems and emergency intelligence systems are analogous and interconnected. Emergency intelligence systems need to possess characteristics such as reparability, cyclicality, and interactivity. Human information society can be compared to a complete ecosystem, where intelligence service and management capabilities for public health emergencies are equivalent to the ecosystem's self-repair and regulation capabilities. Analyzing emergency intelligence systems from an information ecology perspective can endow them with ecosystem traits such as integrity, coordination, stability, cyclicality, and reparability, optimizing internal information system mechanisms, strengthening information circulation and exchange, and forming a harmoniously competitive information environment both internally and externally. From the information niche perspective, information ecological imbalance in public health emergencies leads to changes in information niches. Therefore, optimizing relationships among information actors, information resources, and information systems is necessary to dynamically adjust information niches, promote healthy competition between emergency intelligence systems and the external environment, enhance emergency intelligence system prevention capabilities, enable sustainable exchange between elements in the information ecological environment and the external environment, and stabilize them in reasonable niches.

## 3 Issues in Intelligence Services and Management in the Information Environment

China has initially established a public health emergency intelligence system, achieving considerable progress in human, technology, and system element construction. However, recent performance of emergency intelligence systems in intelligence response reveals that problems mainly concentrate on imbalances among information actors, information technology, information systems, and the information environment within the information ecosystem.

### 3.1 Imbalance Between Information Environment and Information Actors/Systems

Under public health emergency contexts, imbalance between the information environment and information actors/systems (see Figure 2 [Figure 2: see original paper]) leads to intelligence early warning failures, generalized intelligence transmission, and insufficient intelligence utilization depth. The ability of intelligence personnel to use data for crisis early warning and decision rehearsal is directly influenced by the information environment. Currently, insufficient depth in “open crowdsourcing” of data leads to suboptimal information decision-making environments. At the social data openness level, operators control network traffic, access records, location information, and terminal information with broad coverage and high precision, yet other institutions struggle to access operator data. At the government data openness level, Weng Shihong et al. [21] evaluated open data quality from two national-level and 85 provincial platforms including the National Health Commission, China CDC, provincial governments, health commissions, and disease control centers from January 26 to March 25, 2020. Results showed only 12 governments released data refined to the individual level, only two websites provided copy-paste tables, 12 provided analyzable datasets, five provided image tables, and one provided PDF tables. Additionally, China lacks specialized crowdsourcing data collection and analysis platforms, and existing commercial platforms have relatively single subjects for data analysis and decision-making, making optimal decision-making difficult to achieve. The coexistence of information overload and information scarcity often leads to information environment and system imbalance. During public health emergency responses, explosive information channels trigger information noise and pollution. News media, social networks, WeChat public platforms, and other channels disseminate vast amounts of information rapidly, creating a complex overall information landscape with large total volumes but limited effective information. Simultaneously, the depth of mining and utilization of collected and stored data remains insufficient, with inadequate integration of population flow information, medical material information, and living security information held by social institutions, resulting in low data measurability and information scarcity phenomena.

### 3.2 Imbalance Between Information Technology and Information Actors/Environment

During emergency response, imbalance between information technology and information actors affects intelligence perception, collection, and utilization. This imbalance primarily manifests as information technology platforms lacking robust intelligence personnel support. For example, medical adverse event reporting systems suffer from insufficient utilization rates. Cheng Yanmin et al. [22] surveyed reporting system usage across 30 hospitals in Shandong Province regarding systems from the former Ministry of Health and Chinese Hospital Association, revealing only 10.34% of hospitals had used both systems. Additionally, intelligence personnel are constrained by single information sources and insufficiently timely dissemination effects, leading to inadequate intelligence perception. On the other hand, information technology's inability to effectively support the information environment creates imbalance that impacts intelligence analysis and decision-making. In information ecosystems, advanced information technology actively shapes and optimizes the information environment, while lagging information technology development directly constrains it. During public health emergencies, information technology disparities lead to different intelligence perception and response speeds across regions, with significant variations in initial information release times. Developed regions with superior information infrastructure and capabilities perceive information more rapidly, while some underdeveloped districts and counties release information relatively slowly. Furthermore, regions with more advanced information technology can more timely utilize technologies such as temporal correlation analysis, event correlation analysis, and case visualization for multi-dimensional analysis of historical public health emergencies, enabling more effective intelligence support (see Figure 3 [Figure 3: see original paper]).

### 3.3 Imbalance Between Information Systems and Information Actors/Technology

In emergency intelligence system construction, the tendency to prioritize information system construction while neglecting information personnel cultivation directly causes imbalance between information systems and actors. During public health emergencies, if personnel cannot fully utilize information systems, intelligence feedback reflecting event progress will be affected. Lu Yanxia et al. [23] investigated medical personnel information literacy in Baise City, finding that among 1,000 survey respondents, information awareness, knowledge, capability, and training levels were 58.6%, 81%, 8.9%, and 68% respectively, with information capability—encompassing technology application, information retrieval, acquisition, organization, processing, and analysis—being the lowest. Therefore, optimizing internal personnel structure, data awareness, and intelligence literacy is essential to fully realize the collaborative response value of emergency information systems and personnel. Additionally, mismatched information technology development and system application causes imbalance between information systems and technology, affecting both intelligence channel transmission/analysis and intelligence support work. For example, constrained by technical means, collaborative rates among primary healthcare information systems remain low. Chen Quan et al. [24] conducted a national survey of 3,245 primary healthcare institutions, revealing that while information system coverage reached 75%, the usage rate of medical collaboration functions was the lowest. Some primary-level systems also suffered from technical design defects limiting functionality: only 4.34% of institutions achieved all functions specified in the "Basic Functional Specifications for Primary Healthcare Information Systems." Moreover, current information technology application levels cannot support efficient data integration and coordination, with smart city and smart community information services and support capabilities failing to achieve full potential (see Figure 4 [Figure 4: see original paper]).

## 4 Construction of Emergency Intelligence System from the Perspective of Information Ecology

Addressing information ecological imbalance in public health emergency intelligence systems, this study adds two business flows to traditional intelligence workflows: (1) a static ecological balance flow focusing on daily emergency data management fundamentals such as crisis factor database construction, crisis intelligence clue collection systems, data quality management, data fusion and openness, and data standard encoding; and (2) a dynamic emergency management flow focusing on scanning uncertain or abnormal information during initial emergency stages, perceiving crisis intelligence sources, and transmitting from the information environment layer's perception module upward to the technical platform layer's trigger scheduling module to initiate triggered emergency intelligence management and service work, providing foundations for intelligence feedback and decision-making regulation in the information decision layer. The intermediate intelligence business flow activates immediately after dynamic emergency management flow operation, conducting timely dynamic emergency service management responses while ensuring data transmission and connection with the static ecological balance flow.

### 4.1 Overall Operational Framework

The proposed public health emergency intelligence system adopts a "3$×$3" structure comprising three element layers and three business flows (see Figure 5 [Figure 5: see original paper]). Building upon traditional intelligence business flows, the system adds static ecological balance flow and dynamic emergency management flow, incorporating six new modules: information perception, dynamic accumulation, trigger scheduling, fusion and openness, balanced sustainability, and efficient regulation. All element layers participate in three business flows, 自下向上 including: (1) information layer with information perception and dynamic accumulation modules; (2) technical layer with trigger scheduling and fusion and openness modules; and (3) decision layer with balanced sustainability and efficient regulation modules.

**4.1.1 Information Environment Layer** The information environment layer emphasizes "sprout-style" crisis scanning capabilities to address imbalance between information environment and information systems/actors. During peacetime, it systematically accumulates imbalance factors from past crises using crisis intelligence clues for risk prediction and crisis factor capture to address potential crises. During wartime, it focuses on monitoring abnormal data and uncertain information while scanning and perceiving public opinion environments, effectively filtering information noise and valueless intelligence.

**4.1.2 Technical Platform Layer** The technical platform layer emphasizes "refined" emergency intelligence management capabilities and "sustainable" emergency intelligence service capacities, primarily alleviating imbalance between information technology and information actors/environment. During peacetime, beyond using data mining, web scraping, information organization, search, and GIS visualization for multi-source heterogeneous data collection, cleaning, processing, and analysis, the layer integrates data platforms focusing on data fusion and openness—both integrating useful information from social institutions and individual organizations and proactively obtaining government open information to enable intelligence personnel to update data platforms and conduct technical processing and analysis anytime. During wartime, the technical platform layer conducts emergency intelligence situation assessment and support based on accumulated underlying data.

**4.1.3 Information Decision Layer** The information decision layer emphasizes "highly timely" intelligence decision-making capabilities, primarily alleviating imbalance between information systems and information actors/technology. During peacetime, it improves intelligence collaborative power and decision-making quality by enhancing emergency system intelligence personnel information literacy and perfecting competition and incentive mechanisms for intelligence personnel, while also preparing for wartime intelligence decisions through improved analytical decision-making models and knowledge bases. During wartime, the decision layer makes decisions based on data transmitted from the technical platform layer and real-time status of dynamic crisis factors, adjusting according to information ecological environment changes through balance and regulation modules. For example, when public health emergencies develop to large-scale diffusion stages, decisions should shift from specific regional prevention and control to comprehensive real-time dynamic trajectory tracking.

### 4.2 Regulatory Evolution Mechanism

At the information ecological evolution level, the proposed public health emergency intelligence response system first activates the dynamic emergency management flow while traditional intelligence business flows begin data collection, processing, and analysis work. Synchronously transmitting results to the dynamic response flow while receiving support and replenishment from static ecological balance flow's foundational data, processing standards, algorithm prediction models, and situation evolution simulation platforms forms a dynamic-static integrated intelligence analysis and service management system (see Figure 6 [Figure 6: see original paper]).

**4.2.1 Ecological Imbalance Conduction and Trigger Response Mechanisms** Between the information environment layer and technical platform layer, ecological imbalance conduction and trigger response mechanisms optimize the relationship between information environment and information systems. The information environment layer transmits information to the technical platform layer through trigger response mechanisms, providing foundational data and using ecological imbalance conduction mechanisms to deliver medical information, online consultations, and material supply information to information demanders, enabling the decision layer to make optimal service resource allocation choices. Additionally, important knowledge and specialized information formed during public health emergency responses should achieve connectivity between healthcare databases and medical and health system interfaces to ensure timely access to authoritative information and solidify foundations for intelligence emergency support and early warning.

**4.2.2 Dynamic Balance and Regulation Mechanism** Between the technical platform layer and information decision layer, a dynamic balance and regulation mechanism better achieves technical support for decision-making. Based on the intelligence flow system, peacetime-accumulated public health data, institutional data, and population trajectory data are coordinated on data fusion platforms. Through technical optimization systems integrating situation assessment, visual analysis, and population flow simulation modules, when decision-making requires data and system analysis, the dynamic balance and regulation mechanism optimizes available system and platform combinations, integrating them into new intelligence analysis and decision-making processes to achieve fusion and connectivity with emergency support systems such as material scheduling systems and emergency traffic command platforms, thereby providing dynamic emergency management support.

**4.2.3 Intelligence Feedback and Repair Mechanism** Between the information decision layer and information environment layer, an intelligence feedback and repair mechanism enables the information decision layer to react upon the information environment, controlling and regulating intelligence retransmission. Continuously absorbing information from the environment to adjust decisions repairs defects in information technology and systems within the information environment. For example, during emergency response processes, security and confidentiality systems can be established within the ecological cycle system to control and regulate personal information leakage issues that easily arise during data fusion.

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**Abstract:** [**Purpose/Significance**] This paper innovatively constructs an emergency intelligence system from the perspective of information ecosystem element balance, proposing a system that can fundamentally address crises and achieve sustainable service and management. It promotes the formation of a public health emergency intelligence system in China that integrates both "dynamic and static states" and combines "peacetime and wartime" operations. [**Method/Process**] Using literature research methods, this study summarizes current research status on emergency intelligence systems at home and abroad, and analyzes the referential value of information ecology theory for emergency intelligence system construction. From the information ecology perspective, it examines information ecological imbalance phenomena in public health emergencies and proposes an emergency intelligence system model based on a three-layer ecological structure (information environment layer, technical platform layer, and information decision-making layer) that integrates both “dynamic emergency management flow” and “static ecological balance flow” with traditional intelligence workflows. [**Result/Conclusion**] This study proposes a “3$×$3” emergency intelligence system that combines “dynamic and static states” and “peacetime and wartime” operations from the information ecology perspective. The system improves the information ecological environment for emergencies, balances dynamic relationships among information actors, information technology, information systems, and the information environment, and cultivates risk prevention and control capabilities, data sharing and openness capabilities, analytical decision-making capabilities, and resource scheduling capabilities for emergency intelligence response work.

**Keywords:** information ecology theory; public health emergencies; emergency intelligence system