

Research on Digital Transformation of Urban Emergency Management System from the Perspective of Innovation Ecology Theory

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ABSTRACT

Urbanization intensifies safety challenges and strains traditional emergency management systems, hindering effective crisis response. This study explores digital transformation as a solution to enhance response efficacy, constructing a novel 'ecology-mechanism-objective' analytical framework. It analyzes technology-driven, system-driven, and strategy-driven innovation models, examining their interplay with policy, technological, cultural, and economic factors. Based on this analysis, the study proposes tailored implementation pathways for advancing China's urban emergency management capabilities in the digital era, addressing specific contextual needs.

KEYWORDS

Innovation Ecology Theory; Emergency Management; Digitalization; Modernization.

1. INTRODUCTION

China aims to build a safe and development-oriented city by 2035, aligning with its socialist modernization goals. Rapid urbanization has intensified urban risks, exposing limitations in traditional emergency management. To address this, digital transformation has become imperative for enhancing efficiency, intelligence, and resilience in emergency response. Supported by national strategies like the digital transformation initiative and smart city development, the government is actively promoting digital upgrades in urban emergency management.[1] However, disparities in technological infrastructure, economic conditions, and governance approaches have led to uneven progress across regions. This paper examines the key factors influencing the digital transformation of urban emergency management and explores pathways for improvement. By leveraging data sharing, intelligent decision-making, and advanced analytics, cities can strengthen risk prediction and response capabilities, ultimately advancing urban safety and sustainability.

2. THEORETICAL FRAMEWORK AND ANALYSIS

The innovation ecology theory provides a comprehensive lens to examine the digital transformation of urban emergency management.[2] This theory conceptualizes innovation as an ecosystem, emphasizing the dynamic interactions among innovation entities, elements, and the external environment.[3] Within this framework, the digital transformation of urban emergency management is viewed as a complex process driven by multiple stakeholders, integrated resources, and contextual factors.

The analysis adopts an "ecology-mechanism-goal" structure to systematically explore this transformation. The transformation ecology represents the external pressures, encompassing the

innovation environment, such as policy support, legal frameworks, and cultural readiness, which collectively shape the conditions for digital transformation.[3] The transformation mechanism functions as the operational framework, detailing the behavioral logic and processes through which stakeholders—including governments, enterprises, academic institutions, and social organizations—collaborate, compete, and integrate technological, data, and human resources to drive innovation.[4] Finally, the transformation goal reflects the targeted outcomes, focusing on how local governments and other actors respond to and leverage digital advancements to enhance emergency management efficacy. [5]

This tripartite framework underscores the systemic nature of digital transformation, where external influences, internal dynamics, and strategic objectives interact to shape urban emergency management's evolution. By applying innovation ecology theory, the analysis elucidates the multifaceted drivers and processes underlying this transformation, offering a structured approach to understanding its current state and future trajectory.

3. DIGITAL TRANSFORMATION IN URBAN EMERGENCY MANAGEMENT: A CASE-BASED ANALYSIS

Beijing, Chengdu, and Shenzhen exemplify innovative urban emergency management models. Beijing's "Smart Community," Chengdu's tech-driven "China-Europe Cooperation Model," and Shenzhen's megacity-focused system address unique regional challenges.[6] These cases, analyzed through an ecological-mechanism-goal framework, demonstrate how digital solutions enhance community resilience. Chengdu's approach offers national reference value, while Shenzhen's system tackles complex cross-border safety demands.[7] As Shanghai accelerates its emergency management development, these models provide actionable insights for sustainable urban safety governance. The selection of these three cities provides a scientifically valid sample for studying digital emergency management construction, reflecting diverse urban characteristics and practical needs.

(1) Technology-Driven: Chengdu's Smart Platform

Chengdu's smart city emergency management platform exemplifies technology-driven transformation, using advanced tools to enhance efficiency. The city, prone to disasters like earthquakes and floods, integrates sensors and IoT devices to collect real-time data (e.g., weather, fire alarms). AI and big data enable disaster prediction and early warnings, such as pre-storm alerts for public safety and resource preparation.

The platform optimizes resource allocation and command coordination through intelligent scheduling. [8] Mobile apps provide citizens with real-time alerts and escape routes, while emergency personnel use them for task management and information sharing. This improves response accuracy, inter-department collaboration, and public participation.

However, successful digital transformation requires overcoming institutional barriers. Decision-makers must proactively redesign governance models to align new technologies with traditional frameworks, ensuring innovation is sustainably integrated. Chengdu's case highlights the need for organizational adaptability in tech-driven emergency management.

(2) System-driven: Shanghai's digital system

Shanghai's digital emergency management transformation highlights the critical role of institutional culture in systemic reform. Post-COVID, the city established a comprehensive digital framework aligned with its Emergency Response Master Plan, standardizing command, support, and prevention systems. Policy directives and dedicated task forces guide the transition, while technical standards ensure system stability.

Culturally, Shanghai promotes openness and innovation through digital training for staff and interdepartmental collaboration.[9]A unified information platform enables real-time data sharing, supplemented by partnerships with businesses and NGOs. Public engagement is strengthened through awareness campaigns and community drills.

These institutional and cultural shifts enhance emergency response capabilities, demonstrating how systemic digital transformation improves urban resilience against disasters. The integration of governance frameworks, technological infrastructure, and participatory culture forms a replicable model for modern emergency management.

(3) Strategy-driven: Shenzhen's Smart Emergency Management System

Shenzhen's smart emergency management system exemplifies strategy-driven digital transformation, leveraging advanced technology and innovative mechanisms to enhance disaster response.[10]The city's Emergency Command Center oversees public safety management, revising plans and conducting inspections while integrating modern IT solutions.

An online collaborative platform enables real-time information sharing and task coordination across departments, eliminating silos and boosting efficiency. Public participation is encouraged through disaster reporting and feedback. The upgraded command center utilizes GIS, video surveillance, and cross-department coordination for unified response.

Innovations like drones, remote sensing, and robust communication networks ensure rapid data collection and precise decision-making. These measures have streamlined emergency processes, reduced information delays, and improved response accuracy, demonstrating Shenzhen's leadership in smart city emergency management.

4. FACTORS INFLUENCING DIGITAL TRANSFORMATION IN URBAN EMERGENCY MANAGEMENT

(1) Policy Factors: Foundation of Digital Urban Emergency Management

Government policies play a pivotal role in driving the digital transformation of urban emergency management. Supportive regulations, such as China's National Comprehensive Fire Rescue Team Construction Plan (2016–2020) and the National Big Data Development Strategy Outline, provide a legal framework, encourage technological adoption, and allocate resources for digital upgrades.[11] These policies define responsibilities, streamline workflows, and address data-sharing and privacy concerns while promoting collaboration among businesses, academia, and social organizations.

However, challenges persist, including the need for adaptive policy adjustments, robust cybersecurity measures, and efficient interagency coordination. Without timely oversight, policy gaps or misalignment could hinder progress. Effective implementation requires sustained government commitment, private sector engagement, and public-private partnerships to ensure resilience and innovation in digital emergency response systems.

(2) Technical Factors: Driving Digital Urban Emergency Management

Advancements in big data, AI, IoT, and cloud computing are transforming urban emergency management. These technologies enable real-time monitoring, predictive analytics, and automated responses, improving disaster prevention and resource allocation. AI enhances decision-making speed, while IoT and cloud computing facilitate data sharing and operational efficiency. Mobile technologies improve public engagement, and VR/AR support realistic training for emergency personnel.

However, challenges remain, including cybersecurity risks, integration with existing systems, and keeping pace with rapid technological evolution. Effective implementation requires balancing

innovation with data privacy, regulatory compliance, and workforce training. By strategically leveraging these technologies, cities can build smarter, more resilient emergency response systems.

(3) Cultural Factors: The Key to Digitalizing Urban Emergency Management

Cultural factors significantly influence the success of digital transformation in urban emergency management. Public attitudes toward technology, shaped by local values and behaviors, determine whether digital solutions are embraced or resisted. Widespread acceptance and trust in digital tools among residents accelerate adoption, while skepticism or reluctance can hinder progress. Government leadership plays a pivotal role in shaping this cultural landscape by promoting awareness, providing resources, and fostering collaboration.

The culture of social participation and innovation further drives digitalization. Cities that encourage open dialogue, cooperative problem-solving, and inclusive decision-making enable smoother implementation of emergency management technologies.[12]When residents feel their input is valued, they engage more actively, ensuring solutions align with community needs. Conversely, cultural resistance-whether due to distrust of technology or reluctance to change-must be addressed through education, transparency, and participatory governance. Ultimately, aligning digital transformation with local cultural dynamics ensures more effective and sustainable urban emergency management.

(4) Economic Factors: Driving Force Behind Digital Urban Emergency Management

Economic conditions fundamentally shape the digital transformation of urban emergency management. The adoption of digital technologies enhances operational efficiency, reduces costs, and optimizes resource allocation, while also stimulating innovation and attracting investment for sustainable urban development. However, this transition demands substantial financial and human capital, requiring balanced fiscal planning and market-driven strategies.

Key economic considerations include sufficient funding for infrastructure, technology procurement, and workforce training, alongside public-private investment in digital solutions. Cost-benefit analysis ensures efficient resource use, maximizing emergency response effectiveness while minimizing waste. Meanwhile, evolving market demands guide strategic priorities, ensuring digital upgrades align with real-world needs.

Successful digital transformation hinges on coordinated efforts between governments, businesses, and stakeholders to address financial constraints, incentivize innovation, and leverage economic opportunities-ultimately strengthening urban resilience through technology.

5. PATHWAYS FOR DIGITAL TRANSFORMATION IN URBAN EMERGENCY MANAGEMENT

This paper employs an ecological theory to construct a three-dimensional framework (goals, mechanisms, ecology) for analyzing the digital transformation of urban emergency management, addressing gaps in existing research. Building on Tong Xing and Zhang Haibo's (2022) work on emergency management mechanisms, it theorizes transformation pathways through three governance levels: technological connectivity, process-driven actions, and system restructuring. The study explores paths involving urban emergency system arrangements, digital tools, and government management methods, integrating technology with institutional reform for comprehensive urban emergency governance. The framework aims to standardize and explain digital transformation in this context.

(1) Institutional path: Accelerate the top-level design of the digital system construction of urban emergency management

To accelerate the top-level design of urban emergency management digitalization, governments must establish a policy framework with clear objectives, principles, and development pathways, informed

by expert input. Unified standards for data collection, transmission, storage, and sharing, along with system design and security protocols, are essential to ensure interoperability and consistency. An integrated information platform should be developed, incorporating monitoring, early warning, resource allocation, and decision-support systems to enable end-to-end data management. A digital command system is critical to centralize multi-agency resources and enable intelligent, networked decision-making.

Talent development and training programs must be prioritized to enhance professional capabilities, while public-private-academic collaboration can drive innovation and resource sharing.[13]These measures collectively strengthen urban emergency response, safeguarding public safety and assets through a robust, coordinated digital infrastructure.

(2) Technical path: Promote the integration, sharing and security of big data

The digital transformation of urban emergency management leverages emerging technologies like AI, big data, IoT, and blockchain to enhance intelligence, efficiency, and comprehensiveness. Key to this transformation is breaking down information silos by establishing data-sharing platforms and networking mechanisms, enabling interoperability and resource sharing across departments, enterprises, and the public. Open data interfaces and policies foster innovation and public benefit, while collaborative mechanisms improve coordination and response efficiency. Digital literacy is essential for emergency management teams to effectively utilize these technologies. Training in digital skills and mindset shifts is crucial to drive departmental transformation. Simultaneously, robust information security measures-such as data encryption, access controls, and identity verification-must be implemented to safeguard sensitive data, supported by clear policies and regulations.

Strengthening emergency preparedness and attracting big data talent through training and exchange programs are vital. These steps ensure advanced data analysis and management capabilities, enhancing prevention and response. By integrating these approaches, cities can optimize data utilization, improve decision-making, and elevate emergency management resilience.

(3) Management path: Strengthen the digital collaborative scheduling and command of urban emergency management

The digital transformation of urban emergency management, leveraging emerging technologies and service science, enhances rescue efficiency and response speed, ensuring urban safety. Key steps include recognizing the urgency of digital transformation, integrating it into city planning, and establishing a dedicated agency to oversee implementation. Cross-departmental coordination is essential to streamline processes and optimize workflows using digital tools. Investing in a comprehensive emergency management information system is critical, incorporating monitoring, resource scheduling, and decision-support modules while ensuring data security and interoperability. A robust data management mechanism improves data quality and enables data-driven decision-making through analytics.

Capacity building is vital-training professionals, collaborating with experts, and fostering partnerships with universities enhance digital literacy and innovation.[14]Strengthening cooperation among departments, businesses, and the public promotes resource sharing and joint emergency response. Finally, a supervision and evaluation system ensures continuous improvement by assessing digital transformation progress and addressing gaps.

These measures collectively advance the efficiency, precision, and intelligence of urban emergency management, elevating overall safety and resilience.

6. CONCLUSION

In the digital age, traditional and non-traditional security threats intertwine globally, challenging urban emergency management systems. Digital technology, as a key driver of transformation, is reshaping governance, market roles, and societal interactions, introducing both challenges and opportunities for emergency management. Amid rapid technological advancements and a complex external environment, proactive adaptation is essential to modernize urban emergency systems and capabilities.

The 21st century has brought evolving risks, demanding reflection on China's institutional strengths in emergency management and the new threats cities face. Addressing these challenges will advance the modernization of emergency systems, supporting high-quality economic and social development.

Moving forward, China must ground efforts in its unique context, leveraging existing research and a "human-centric" approach. Key priorities include defining emergency management boundaries, identifying systemic bottlenecks, and integrating digital technologies to enhance efficiency. This will pave the way for comprehensive, innovative emergency management solutions.

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