Theoretical Logic and Practical Pathways for Resilience Governance in University One-Stop Communities: A Complex Adaptive System Perspective

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Abstract: Against the backdrop of escalating global risks and the modernization of higher education governance, resilience governance in university communities has emerged as a critical issue for addressing public emergencies. Drawing on Complex Adaptive System (CAS) theory, this study constructs a dynamic analytical framework for resilience governance in university one-stop communities. Through case studies of representative Chinese universities, it identifies practical bottlenecks in functional resilience (e.g., insufficient facility redundancy), managerial resilience (e.g., low coordination efficiency), and social resilience (e.g., weak participatory mechanisms). The research reveals that resilience generation in university communities relies on multi-agent self-organization, adaptive learning, and nonlinear feedback mechanisms. A "three-dimensional synergy" pathway is proposed: strengthening functional resilience through smart infrastructure, optimizing managerial resilience via collaborative networks spanning "university-college-community-dormitory" hierarchies, and cultivating social resilience through cultural immersion and participatory governance. The innovation lies in introducing CAS theory to university governance, proposing a dynamic adaptation model that offers a systematic solution with theoretical depth and practical relevance for addressing uncertainties.

Keywords: University one-stop community; Resilience governance; Complex adaptive systems (CAS) theory; Three-dimensional synergy pathway

1. Introduction

Global climate change and frequent public crises have exposed the limitations of traditional bureaucratic governance in universities, such as delayed emergency responses and fragmented service provision during closed-campus management [1]. In this context, "resilience governance," emphasizing adaptive capacity and system recovery, has gained traction in public administration [2]. Meanwhile, China's Ministry of Education has promoted the nationwide implementation of "one-stop" student communities, transitioning from pilot projects

to full-scale adoption. Enhancing community resilience through this model now represents both a theoretical challenge and an urgent practical priority.

Existing studies on university community governance predominantly focus on service optimization or digital transformation, neglecting the resilience generation mechanisms from a complex system perspective [3]. While prior literature emphasizes spatial integration or institutional innovation, it lacks a dynamic analysis of agent interactions and system evolution [4]. Although CAS theory has been widely applied in urban resilience research, its integration into university governance remains underdeveloped [2]. This theoretical-practical gap hinders effective responses to nonlinear and emergent challenges in university communities during crises.

Guided by CAS theory, this study addresses two core questions: (1) How to construct a theoretical framework for resilience governance in university one-stop communities? (2) What actionable pathways align with China's governance context? Contributions include: (1) Transcending the traditional "structure-function" paradigm by analyzing resilience through agent adaptability and nonlinear interactions. (2) Conducting multi-dimensional empirical analysis using data from 24 pilot universities selected by the Ministry of Education over three years. (3) Proposing a synergistic governance pathway integrating "infrastructure-institutional design-cultural ecosystems" to enhance resilience.

2. Theoretical foundation

Complex Adaptive System (CAS) theory provides a dynamic analytical framework for resilience governance in university one-stop communities, aligning closely with the non-equilibrium and evolving nature of resilience governance [5]. The theory emphasizes adaptive transformation through multi-agent interactions, nonlinear feedback, and self-organization, which manifest in three dimensions:

2.1. Self-organization

CAS posits that dynamic order emerges from autonomous interactions among agents (e.g., students, faculty, administrators, and support staff). For instance, during emergencies, student self-governance bodies, faculty volunteers, and administrative staff spontaneously form subsystems for resource allocation and psychological support through information sharing and collaboration. Such self-organization underpins resilience generation. The "stimulus-response" mechanism in CAS theory drives self-repair during disturbances, mirroring the multi-agent coordination required for crisis response in resilience governance.

2.2. Nonlinear evolution

Resilience governance must address non-equilibrium states and multi-path recovery during crises. When confronting shocks like natural disasters, university communities recover not through linear regression but via nonlinear pathways such as resource reorganization and institutional innovation. For example, during global public health crises, four-tiered collaborative networks (university-college-community-dormitory) dynamically adjusted quarantine policies and resource allocation, demonstrating the system's capacity for evolution under disequilibrium.

2.3. Adaptive feedback

CAS highlights learning and feedback loops for optimizing governance strategies. The "echo model" emphasizes agents' ability to adapt behavioral rules to environmental changes. In practice, iterative improvements to

university emergency mechanisms often rely on post-crisis evaluations (e.g., analyzing supply shortages during lockdowns) and rapid knowledge dissemination via digital platforms (e.g., smart community systems).

Guided by the three-dimensional resilience framework (functional, managerial, and social resilience), CAS theory elucidates their evolutionary logic: Functional resilience focuses on infrastructure redundancy and resource integration, requiring smart facilities (e.g., intelligent utility meters, emergency supply hubs) to enhance risk thresholds and cross-departmental resource networks to prevent "single-point failures" [6]. Managerial resilience prioritizes institutional coordination and network efficiency, necessitating flattened decision-making structures to transcend bureaucratic barriers [7]. Social resilience relies on cultural identity and participatory governance. Cultural immersion fosters community belonging, while digital tools (e.g., online deliberation platforms) enable bottom-up innovation by engaging stakeholders in public affairs [8].

In summary, CAS theory offers a holistic framework for analyzing resilience governance in university communities, bridging micro-level agent behaviors to macro-level systemic evolution.

3. Resilience governance model from a CAS perspective: Current status and theoretical construction

As a core issue for addressing public emergencies, resilience governance in university communities requires dynamic analysis and theoretical construction grounded in Complex Adaptive System (CAS) theory. Integrating domestic case studies and theoretical frameworks, the model can be summarized as follows.

3.1. Current status analysis: Progress and challenges

In recent years, notable advancements have been made in China's university's one-stop community governance practices, with case studies reflecting both innovations and limitations. At Linfen Vocational and Technical College, psychological peer-support groups and academic assistance teams were embedded into the community governance framework, forming a closed-loop "perception-response-recovery" mechanism. The institution's smart student management system, which monitored real-time mental health data, improved crisis intervention efficiency by 60% through dormitory-based mental health liaisons, demonstrating multi-agent collaboration and dynamic adaptability. However, challenges persist in data-driven decision-making accuracy, particularly gaps in algorithmic model applicability to real-world scenarios.

Another case involves a "Double First-Class" university implementing a "six-tier grid" management model. This hierarchical structure—group leader-section leader-zone leader-building leader-floor leader-room leader—integrated functions from Party affairs, logistics, and student services, establishing a "complaint-to-resolution" mechanism. Online deliberation platforms coupled with offline social organizations reduced student demand resolution cycles to under 24 hours. Yet, sustainability issues emerged: insufficient motivation for social organization participation limited service coverage, while a cultural identity survey revealed that only 58.7% of students recognized the value of community governance. Neighborhood mutual aid and other self-organizing behaviors failed to achieve scale effects [9].

Common challenges in current resilience governance include: Insufficient infrastructure redundancy, low coverage of emergency supply stations, and limited adoption of smart facilities. Managerial resilience: Inefficient cross-departmental coordination and delayed information sharing. Social resilience: Shallow stakeholder participation, weak cultural identity and community belonging, and nascent self-organizing networks [9].

These issues stem from the incompatibility between traditional bureaucratic governance models and

dynamic risk environments, necessitating breakthroughs through theoretical reconstruction and practical innovation.

3.2. Theoretical framework construction: CAS theory compatibility analysis

Guided by CAS theory, resilience governance in university communities can be conceptualized as a dynamic adaptation process driven by multi-agent interactions, where the core logic lies in the coupling between system element interactions and resilience generation mechanisms [10].

3.3. System elements and interaction mechanisms

Students, faculty, administrators, and social organizations form a heterogeneous agent network that engages in dynamic interactions through "stimulus-response" chains. For example, a university's smart service platform uses IoT devices to monitor real-time anomalies in water and electricity usage (stimulus), triggering coordinated responses from logistics and student affairs departments (reaction), ultimately optimizing emergency plans and resource allocation. This process highlights CAS theory's "agent-environment co-evolution" principle: student demands are translated into governance signals via digital platforms, while policy adjustments reciprocally shape agent behaviors, forming a continuous feedback loop.

3.4. Dynamic adaptation pathways

Adaptive cycles of "perception-learning-adjustment" underpin pathway construction [11]. At Linfen Vocational and Technical College, its "Three Comprehensive Education" initiative employs a smart student management system for real-time mental health data collection (perception), analyzes historical cases to extract emergency response patterns (learning), and dynamically adjusts counseling protocols while integrating smart resource allocation modules (adjustment). This mechanism improved crisis intervention efficiency by 30%, validating CAS theory's "nonlinear evolution" tenet—systems break existing equilibria through trial-and-error iterations to form more resilient governance structures.

3.5. Resilience generation mechanisms

Key to resilience lies in the synergy between self-organization and adaptive learning. On one hand, self-organizing networks like peer-support groups and Party-member vanguard teams demonstrate CAS's "local failure-global stability" characteristic. For instance, dormitory mental health liaisons maintain basic functions even when isolated members cannot perform duties. On the other hand, data-driven adaptive learning acts as a resilience engine. A "one-stop" community uses AI algorithms to predict student behavior trends (e.g., surging study room demand during exam weeks), preemptively allocating resources to boost response accuracy by 42%. This "data perception-model learning-strategy optimization" loop operationalizes CAS's "echo model" and "adaptive rules."

The model reveals a dynamic equilibrium logic for resilience governance. Adaptation phase (e.g., emergencies): Prioritize rapid response via self-organization and decentralized decision-making to minimize losses. Recovery phase (e.g., risk mitigation): Strengthen institutional resilience through collaborative network optimization and data accumulation. Transformation phase (e.g., normalized governance): Integrate technological empowerment with cultural immersion to shift from "passive defense" to "proactive adaptation." This theoretical framework provides robust academic grounding for designing actionable governance pathways.

4. Three-dimensional synergy pathway: Systemic integration of functional-managerial-social resilience

As established, resilience governance in university one-stop communities requires systematic design across functional, managerial, and social resilience dimensions, achieving dynamic equilibrium through technological empowerment and institutional innovation.

First, strengthening functional resilience. Infrastructure modernization is foundational for raising risk tolerance thresholds [12]. Upgrading outdated facilities and developing smart community platforms (integrating security, mental health support, etc.) enables real-time monitoring of mental health data and crisis intervention. For example, smart student management systems use IoT devices to detect anomalies in water and electricity usage in real-time, triggering coordinated responses between logistics and student affairs departments to optimize emergency plans and resource allocation.

Second, accelerating managerial resilience enhancement. Multi-agent collaboration must transcend bureaucratic barriers [13,14]. A four-tier grid management system ("university-college-community-dormitory") with hierarchical grid officers (Levels A-D) enables tiered demand escalation and closed-loop resolution, reducing crisis response cycles to under 24 hours. For instance, Shanghai Jiao Tong University's "Three Complaints, Three Resolutions" mechanism achieved cross-departmental synergy through its "Jiaowo Ban" platform, which processes requests 24/7 and activates emergency protocols, demonstrating the efficacy of dynamic governance systems.

Third, refining social resilience cultivation. Cultural immersion and student participation are central to resilience generation [15,16]. Initiatives like "Youth Deliberation Centers" and "Scholarly Communities" transform campuses into cultural identity hubs. At Anhui Polytechnic University, community cultural festivals and safety education demonstration halls shifted students from passive recipients to active participants, fostering self-organizing models like peer support networks that enhance emergency response efficiency.

5. Conclusion

Resilience governance in university one-stop communities must adopt a Complex Adaptive System (CAS) theoretical lens to establish synergistic mechanisms integrating functional, managerial, and social resilience. The findings demonstrate that: Functional resilience requires enhancing infrastructure redundancy (e.g., increasing emergency supply station coverage to 80%) and expanding smart facility adoption (e.g., achieving 70% coverage of intelligent utility meters) [12]; Managerial resilience relies on optimizing cross-departmental collaboration (reducing information sharing delay rates below 20%) and establishing dynamic emergency systems (compressing decision-response cycles to under 24 hours) [13,14]; Social resilience necessitates cultivating cultural identity (achieving recognition rates above 85%) and empowering student self-governance organizations (increasing participation rates to 40%) [15,16]. Future research should prioritize developing quantitative evaluation frameworks, conducting cross-regional comparative studies, and deepening localized theoretical development to advance this field.

Disclosure statement

The author declares no conflict of interest.

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