

Article

Approach to Establishment of Self-Organizing Governance in Digital Government Systems

Hua Guo ^{1,*}, Ruoxin Pang ¹, Liwen Liu ¹ , Xiaojiang Xing ² and Hui Li ³

¹ Business School, Hohai University, Nanjing 211100, China; 221313030034@hhu.edu.cn (R.P.)

² Nanjing Jiangbei New Area Science and Technology Innovation and Big Data Administration Bureau, Nanjing 211800, China

³ Nanjing Jiangbei New Area Urban Digital Governance Center, Nanjing 211800, China

* Correspondence: guohua@hhu.edu.cn; Tel.: +86-133-0519-0637

Abstract

As digital government systems evolve, increasing complexity in information interactions has challenged traditional hierarchical governance models, which often struggle in dynamic and cross-sectoral contexts. This study aims to identify the structural patterns of government information interaction and to develop a testable adaptive governance approach that supports sustainable digital government evolution. Drawing on IT alignment theory and complex network analysis, this study reconceptualizes digital government as a complex adaptive system and reveals the heavy-tailed distribution, structural stability, and self-organizing tendencies of government information networks. Building on these findings, the study develops and operationalizes a self-organizing adaptive governance framework—featuring fractal design, dynamic alignment, and layered modular coordination—into 11 governance rules. By shifting the focus from static alignment to adaptive structural coordination, this research advances a new pathway for the sustainable and resilient evolution of digital government systems.

Keywords: digital government; IT alignment; complex network; self-organization; adaptive governance; sustainable digital governance

1. Introduction

The practice of “digital government” can be traced back to the early 2000s. It is generally understood that digital government aims to enhance the intelligence, resilience, and compatibility of government governance through process reengineering, resource integration, and system integration [1]. The Organisation for Economic Co-operation and Development (OECD) released a report in December 2024 titled “Digital Public Infrastructure for Digital Government,” defining digital public infrastructure as secure and interoperable digital information systems. The report points out that digital public infrastructure can significantly enhance the efficiency of digital government governance, helping digital governments achieve data sharing, service delivery, and cross-departmental collaboration. Therefore, as the core infrastructure of digital government, information systems play a critical supporting role. Its governance model—the institutional arrangements formed around architecture design, authority allocation, business collaboration, and resource allocation—directly determines the operational effectiveness and developmental potential of digital government.



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Over the past two decades, digital government development has broadly progressed through three phases: the initial digital technology phase, emphasizing information digitization, government website construction, and infrastructure deployment; the subsequent business transformation phase, leveraging information technology to drive organizational change, strengthen project management, and promote information sharing; and the current contextual phase, where technological innovation addresses complex governance demands to advance sustainable development [2]. This evolutionary trajectory is broadly consistent with the transformation from early e-government (often characterized as e-government 1.0), which primarily focused on information digitization and online service provision, to more integrated and participatory models associated with e-government 2.0 and digital government. This study emphasizes the structural and governance implications underlying these transitions.

Early digital government systems in China were highly dependent on the administrative system, forming a layered and centralized governance model. Entering the 14th Five-Year Plan period, the central government of China proposed integrated requirements for “large platforms, big data, and comprehensive systems,” emphasizing cross-departmental data sharing and business collaboration. Platform-based collaboration models gradually became mainstream. However, as digital government in China entered more diverse, complex, and uncertain application scenarios, the platform model revealed limitations such as insufficient scalability and constrained innovation, hindering the system’s continuous optimization and operation. Specifically, the design, development, operation, and maintenance of the platform are all controlled and managed by a specific department. This centralized, platform-oriented governance arrangement has a profound impact on the sustainable development of China’s digital government system.

From a sustainability perspective, digital government systems in China should be evaluated not only by short-term outcomes or technological advancement, but by their capacity to maintain stable functioning, adapt to evolving governance and technological environments, and support continuous system evolution. In digital government contexts, environmental changes mainly manifest as growing cross-departmental complexity, rapid expansion of application scenarios, and the dynamic evolution of data and technology ecosystems. These shifts place increasing pressure on existing governance arrangements and expose structural rigidities in traditionally centralized or fragmented models.

Accordingly, sustainability should be understood as a core governance objective requiring institutional arrangements that enable long-term stability, adaptability, and coordinated evolution. Governance approaches dominated by rigid hierarchy or fragmented collaboration often lack endogenous adjustment mechanisms. Therefore, adaptive governance that supports self-organization and structural coordination is essential for the sustainable development of digital government systems.

Existing information practices and theoretical research predominantly rely on structured technological approaches that align systems and operations in a top-down manner, placing excessive emphasis on overall architecture design. Such approaches increase system complexity and reduce responsiveness to contextual changes. In the face of highly heterogeneous application scenarios and rapidly expanding interconnections, rigid preconfigured systems struggle to accommodate dynamic requirements, making complexity management a critical challenge for digital government governance. Janssen and Voort [3] propose the concept of “adaptive governance,” which enhances agility in responding to uncertainty and adapting to environmental changes through decentralization and multi-stakeholder participation. Adaptive governance possesses four key characteristics: bottom-up decentralized decision-making, coordination and integration of internal and external capabilities, broad participation and internalization of development, and continuous adjustment to

address uncertainty [4]. From this perspective, IT consistency theory provides a critical analytical lens for understanding how structural fit can be maintained under conditions of continuous change. In addition, complex network theory offers a macro-level perspective for understanding information interactions among government departments. Unlike social network analysis, which focuses on node attributes and collaborative communities, complex network analysis simplifies network structures while preserving key characteristics to reveal the core mechanisms of information interaction [5].

This study employs a data-driven and theory-guided analytical approach, using structural consistency as the analytical entry point to examine patterns of government information interactions to address these challenges. Drawing on IT consistency theory, complex network theory, and modularity theory, this paper proposes an adaptive governance framework to support the sustainable evolution of digital government systems.

This study contributes by (i) constructing and comparing decision-making and implementation interaction networks from policy texts, (ii) linking empirically observed topological properties to the limited adaptability of existing governance models in dynamic and cross-sectoral contexts, and (iii) operationalizing adaptive governance into falsifiable principles and governance rules for digital government systems.

2. Related Research

2.1. Digital Government Collaboration

Digital government collaboration is fundamentally an inter-organizational governance issue rather than a purely technical integration task. Empirical research shows that the success of inter-organizational information sharing depends jointly on organizational factors, political institutional arrangements, and information/technological infrastructure, indicating that collaboration emerges from multi-dimensional governance conditions [6].

In European digital government practice, collaboration is often institutionalized through interoperability governance and “once-only” [7] information reuse, aiming to reduce administrative burden by enabling cross-agency data exchange under shared principles such as user-centricity, security, and once-only provision.

These insights illustrate: when cross-department collaboration expands across scenarios, interaction structures may become increasingly uneven (e.g., hub-dominant and heavy-tailed), which makes it necessary to examine not only whether collaboration exists but also how it is structurally organized across decision-making and implementation layers.

2.2. Digital Government Governance

Digital government governance concerns how authority, accountability, standards, and data arrangements are coordinated to sustain digital transformation; it is widely recognized that transformation is not merely technology adoption but a reconfiguration of organizational structures and governance. Dunleavy [8] highlights reintegration and holistic, needs-oriented structures enabled by digital technologies, emphasizing the co-evolution of administration and digital infrastructure.

Across political systems, adaptation typically faces a shared tension: increasing responsiveness and learning under uncertainty while preserving institutional stability and accountability. Adaptive governance [3] has been proposed precisely to manage this tension by improving the capacity to adapt while preventing instability and protecting accountability.

In China, digital government often advances through platform-based integration and strong administrative coordination capacity [9], which can accelerate consolidation and service integration in key scenarios; however, as scenario diversity grows, governance needs to move from “static alignment” to adaptive coordination that can scale while preserving

stability and accountability—an issue this paper addresses by deriving self-organizing governance rules from observed interaction structures.

2.3. Digital Government and Its Systems

Digital government systems constitute a set of interconnected information systems deployed to achieve digital government objectives. While digital government operates within a broader public governance ecosystem—including public data ecosystems and open government initiatives—government information systems remain the core operational infrastructure through which data exchange, service integration, and cross-departmental coordination are realized. In the United States, such systems encompass five domains: government-to-citizen (e.g., portals), government-to-business (e.g., e-taxation), government-to-government (e.g., crisis response), internal efficiency enhancement (e.g., e-training), and cross-departmental infrastructure (e.g., electronic authentication) [10]. These interaction domains (e.g., G2C, G2B, G2G) have been widely adopted in international digital government research and practice, including in OECD and UN e-government frameworks. China's efforts began with the 1993 "Golden Project" initiatives, including "Golden Tax," "Golden Customs," and "Golden Shield," later expanding into multiple domains such as public services and urban management [11]. Cross-domain application scenarios demand system flexibility and agility [12,13], posing challenges for coordinating system architecture and governance structure design.

In the digital government domain, system architecture not only delineates the overall relationships, hierarchical divisions, and functional integration methods among components but also directly impacts system interoperability and overall government efficiency [14]. In recent years, platform-based and modular system architectures have become the mainstream approach for digital government system development. Standardized interfaces and unified data models facilitate information resource sharing and business process coordination [15].

The governance structure defines the governing entities, responsibilities, and collaborative relationships of information systems, providing institutional safeguards for system operation [16]. At different developmental stages, the governance structure of digital government systems exhibits significant variations. The digital technology phase predominantly employs vertical hierarchical division of labor, emphasizing centralized control, clear responsibilities, and standardized processes. The business transformation phase introduces flat governance and networked governance to break down information silos and bridge process gaps [17]. In the contextualization phase, systems must perceive contexts and provide services on demand; blind pursuit of overall coordination can instead lead to inefficiency [18,19].

Transparency is increasingly treated as a core governance attribute of digital government systems, but the literature shows that more transparency does not automatically translate into higher value unless it improves the usefulness of digital government outputs for stakeholders [20]. From a governance and organizational perspective, transparency should be understood as something constructed through interactions among governments and stakeholders, involving strategic choices, cognitive processing, and institutional constraints—meaning transparency outcomes depend on how information is framed, released, and interpreted rather than on disclosure alone [21]. For this paper, transparency matters because it can influence how information-interaction networks form and evolve: stronger transparency and open-data practices may broaden participation and diversify ties at the implementation level, while also increasing the need for coordination mechanisms to maintain stability, accountability, and decision–execution continuity under expanding interaction complexity.

2.4. Research Gap

Structured information system governance techniques offer a phased “Vision-Business-System-Technology” framework and panoramic governance objective control [6,22], promoting artifact and service reuse with compliant operations. However, top-down approaches risk structural rigidity and inadequate requirement understanding, leading to implementation distortions. Existing research has analyzed the gap between governance models and digital government practices. However, theoretical support for how to develop and standardize governance systems remains lacking [23].

Research has not yet noted that in the context of cross-departmental data integration and comprehensive use of big data, the actual growth trajectory of government information interaction does not necessarily follow the recursive rules of classic networks, and may even diverge from pre-structured systems. When business growth deviates from the structural patterns of governance systems, the adaptability of digital government inevitably faces bottlenecks, which is detrimental to the sustainable development of digital government governance. Therefore, this paper adopts a dual perspective of adaptive governance and complex networks to analyze the operational requirements, system architecture, and governance structure of digital government systems, revealing the organic connection between operation and governance, and providing recommendations for the sustainable development of digital government systems.

3. Research Framework

This paper examines how digital government systems can achieve sustainable operation under complex and dynamic governance conditions. It views adaptive governance in digital government systems as the intrinsic coupling and organic unity among three elements: government information interaction networks that dynamically adapt to application contexts, digital government system architecture, and digital government governance structures. Government information interaction networks reveal the operational requirements and information flow patterns of digital government practice, while system architecture and governance structure represent the formalized specifications and institutionalized implementation of these real-world patterns. Structural coordination among these three elements is critical for the practical operation of digital government systems: high consistency fosters the growth and effective use of formal systems, whereas low consistency often leads to the adoption of workarounds.

Specifically, digital government systems are formally established and managed by organizations to deliver digital government services. Ideally, cross-boundary information flows should traverse these formal systems. However, due to environmental complexity and task urgency, predefined procedures and collaboration methods often fail to meet contextual application needs. Consequently, users resort to workarounds such as informal systems, social media, ad hoc spreadsheets, emails, and offline communication [24]. While these unofficial practices may enhance flexibility and responsiveness in the short term, they undermine information consistency, availability, and reliability over the long term. This ultimately weakens governance performance and leads to strategic misalignment [25].

To address these issues, this paper adopts a hybrid “data-driven-theory-derived” approach. First, it measures information interaction relationships in typical governance cases to identify network patterns. Second, it analyzes the governance problems reflected in these patterns. Finally, it derives a vision, framework, and rule set for the adaptive governance of digital government systems based on relevant core theories. By promoting dynamic structural consistency between formal systems and operational realities, this approach aims to enhance the contextual adaptability and long-term sustainability of digital government systems, as illustrated in Figure 1.

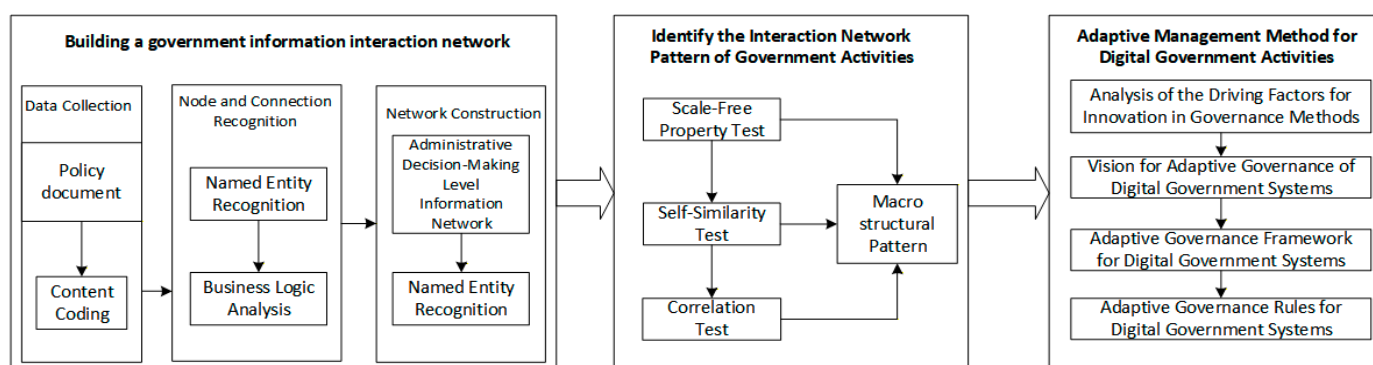


Figure 1. Research Framework.

4. Analysis of Network Patterns in Government Information Interaction

4.1. Government Information Interaction Network: Network Construction Based on Governance Scenarios and Levels

4.1.1. Case Selection and Data Collection

Digital government governance encompasses numerous cross-departmental and cross-domain operational scenarios in China. Among these, routine governance and emergency governance represent two highly alternating, mutually influencing yet distinct governance scenarios that are representative in practical implementation. Shanghai and Jiangsu are pioneering demonstration areas for the development of digital government in China. Jiangsu Province, which includes 13 prefecture-level cities, has a COVID-19 emergency management scenario that is highly typical and complex, with the epidemic's duration covering the entire emergency response process. It involves multiple government functional departments and can reflect relevant characteristics of digital government emergency governance. By identifying and analyzing information interaction network patterns, it provides support for deriving adaptive governance methods. Shanghai has a high level of urbanization and complex traffic management needs. As a core component of urban infrastructure, city traffic is a fundamental governance area closely related to social and economic development and the daily lives of the public, and it can reflect the current state of routine governance in China's digital government.

Based on data integrity and availability, this study selects Shanghai's urban transportation routine governance and Jiangsu Province's COVID-19 emergency management as typical cases, corresponding respectively to routine and emergency governance within the digital government framework. The urban transportation routine governance network aims to establish transportation systems and coordinate transportation development, addressing diverse governance scenarios within the city's transportation sector. The sample period spans the past three years, from 31 December 2021 to 31 December 2024. The COVID-19 emergency management network encompasses functional departments including health, emergency response, transportation, finance, human resources, and commerce, while involving multiple governance subjects such as finance, education, healthcare, elderly care, and technology. It collaboratively advances two core objectives: epidemic prevention and control, and the emergency operation of the economy and society. The sample period is defined as the duration from the outbreak of the pandemic to the conclusion of the Level 2 emergency response, spanning 26 December 2019 to 27 March 2020.

Policy documents systematically document information sharing, exchange, and utilization among government departments, providing semantic information for constructing an information interaction network. This study collected policy documents from the Peking University Law Database (Peking University Law Database: <https://www.pkulaw.com/>, accessed on 25 January 2026) and local government portals. To ensure the completeness,

traceability, and comparability of policy texts, this study used the Peking University Law Database (PKULaw) as a structured policy retrieval source, and local government portals as the original publication source for cross-checking and supplementation. PKULaw was chosen because it provides systematic indexing by region, issuing authority, date, and document type, which is particularly useful for identifying policy texts related to cross-departmental governance. Local government portals were used to verify official publication information and to supplement documents that were publicly released online but were difficult to retrieve in a standardized way from the database.

For Shanghai urban transportation governance, the retrieval scope covered policy documents issued between 31 December 2021 and 31 December 2024, using combinations of keywords such as “urban transport,” “comprehensive transport,” “traffic management,” and “transport coordination.” For Jiangsu COVID-19 emergency governance, the retrieval scope covered documents issued between 26 December 2019 and 27 March 2020, using keywords such as “COVID-19 prevention and control,” “emergency response,” “joint prevention and control,” and “resumption of work and production.” After excluding duplicate documents originating from higher-level policies, internal management documents (such as operational guidelines and commendation awards), and documents lacking inter-organizational interaction relationships, the final dataset comprised 313 routine urban transportation governance policy documents and 184 COVID-19 emergency management policy documents.

4.1.2. Relationship Identification and Network Construction

Government governance encompasses two levels: administrative decision-making and governance execution [26]. Administrative decision-making emphasizes cross-departmental resource integration and information sharing; therefore, it can be reflected in the process of policy formulation. Governance implementation refers to the formal arrangements for policy enforcement and is typically manifested in the actual execution of activities specified in policy documents. Using named entity recognition and content analysis, we extract the actors involved in information interactions from policy texts. Specifically, information-interaction ties at the administrative decision-making level are identified by extracting co-issuing entities from policy releases: we assume that if two departments co-occur in the policy title, this indicates an information-interaction relationship between them. In contrast, relationships at the governance implementation level are derived through business-logic inference: we extract policy measures related to collaborative governance and, based on semantic interpretation, determine the governance actors, objects, and their relationships, which are then treated as information-interaction relationships at the implementation level. Content coding was performed by two teams with cross-checking, resolving discrepancies through discussion. The final results identified 60 participants and 130 information interaction relationships at the decision-making level for routine urban traffic governance, along with 74 participants and 1119 relationships at the implementation level. For COVID-19 emergency management, 23 participants and 49 relationships were identified at the decision-making level, alongside 170 participants and 1352 relationships at the implementation level. Among them, the decision-making layer network is smaller in scale compared to the execution layer network. This is reasonable because joint issuing/co-signing relationships reflect a more ‘formal and selective’ level of cross-departmental collaboration, whereas execution-level measures generate denser business interactions. Moreover, this paper does not train prediction models that rely on large samples on these networks, but rather observes their structure and measures their network characteristics.

By aggregating information interaction relationships, we constructed information interaction networks for two scenarios: routine urban transportation governance (Decision

Network Net 1 and Implementation Network Net 2) and COVID-19 emergency management (Decision Network Net 3 and Implementation Network Net 4). Network nodes represent governance entities and objects, while edges denote information interactions. Edge weights correspond to cumulative relationship frequencies. All interactions stem from information behaviors documented in policy records, with cross-boundary information flows facilitated by both formal systems and informal workarounds.

4.2. Network Patterns of Information Interaction: Complex Topologies Exhibiting Scalelessness, Self-Similarity, and Structural Persistence

4.2.1. Network Topology Measurement Methods

Network topology can summarize the organizational methods of government information interaction and provide a basis for the derivation of adaptive governance principles and falsifiable governance rules. In a scale-free network, the probability $P(k) \sim k^{-\gamma}$ (γ being the power exponent) that a randomly selected node has k connections holds. In this study, $P(k)$ is estimated empirically from the observed network as a frequency-based probability. Let N be the total number of nodes and N_k be the number of nodes with degree. The empirical degree probability is computed as:

$$P(k) = \frac{N_k}{N}$$

The formula for calculating the complementary cumulative degree is:

$$\bar{F}(k) = P(K \geq k) = \sum_{x=k}^{k_{max}} P(x)$$

This study tests scale-free properties through regression analysis of complementary cumulative degree distributions, expressed as: $y = ax^b$. The power-law bias is examined using the Belehadek equation, expressed as: $y = a(x - b)^c$.

Self-similarity typically manifests as a power-law relationship between the number of nodes and the diameter of the fractal object. This paper employs the renormalization group method of the burning box covering algorithm [27] to test self-similarity. The network is covered with N_B boxes of size l_B , such that the fractal dimension d_B satisfies $N_B \sim l_B^{-d_B}$. The specific process is as follows: Starting from a random node, draw a circle with radius l_B . Then, select a random point within the circle as the new center and draw a circle with radius l_B . Next, merge nodes and continue iterating until all points within the box are separated by no more than l_B , completing the box coverage.

The clustering characteristics of a network are determined by its exponent γ : $0 < \gamma < 2$ indicates a heavy-tailed scale-free network; $2 < \gamma < 3$ indicates a classical scale-free network; $\gamma > 3$ indicates a scale-free network tending toward a small-world network [28]. For a fractal network, the number of boxes N_B consistently follows a power-law distribution across all scales l_B .

4.2.2. Complex Network Pattern Recognition

(1) Scalelessness

Pure power-law tests reveal that all networks exhibit γ values below 2, indicating heavy-tailed distributions and scale-free characteristics (see Table 1). In contrast, the urban traffic governance network exhibits lower goodness-of-fit, indicating less pronounced power-law characteristics and a mixed structure. Meanwhile, the COVID-19 emergency management network shows significantly higher goodness-of-fit for shifted power-law models than pure power-law models, suggesting power-law deviation or node concentration.

Table 1. Scalelessness Tests for Government Information Interaction Networks.

Network		γ		R-Square		Adjusted R-Square		Prob > F	
		Pure Power Law	Shifted Power Law	Pure Power Law	Shifted Power Law	Pure Power Law	Shifted Power Law	Pure Power Law	Shifted Power Law
Routine Urban Traffic Management	Net 1	0.408	0.494	0.398	0.404	0.388	0.383	***	***
	Net 2	1.281	1.659	0.399	0.399	0.390	0.382	***	***
COVID-19 Emergency Management	Net 3	0.507	4.235	0.860	0.992	0.850	0.991	***	***
	Net 4	0.445	0.748	0.946	0.996	0.945	0.996	***	***

Note: *** $p < 0.001$. Net 1: Information interaction network in urban traffic normal governance scenario (decision-making network). Net 2: Information interaction network in urban traffic normal governance scenario (execution network). Net 3: Information interaction network in COVID-19 emergency management scenario (decision-making network). Net 4: Information interaction network in COVID-19 emergency management scenario (execution network).

(2) Self-similarity

All networks exhibit positive fractal dimensions and high model fit, demonstrating fractal structure and self-similarity, as shown in Table 2. Compared to routine urban traffic governance, the emergency management network for the COVID-19 pandemic displays more pronounced fractal characteristics, featuring a more complex network structure, greater hierarchical levels, and overall tighter cohesion. Compared to the operational-level network, the decision-making-level network exhibits a more regular structure with weaker complexity features.

Table 2. Fractal Analysis of Government Information Interaction Networks.

Network		d_B	R-Square	Adjusted R-Square	Prob > F
Urban Transportation Routine Governance	Net 1	0.498	0.980	0.978	***
	Net 2	0.548	0.978	0.975	***
COVID-19 Emergency Management	Net 3	2.158	0.980	0.970	**
	Net 4	4.365	0.994	0.991	**

Note: ** $p < 0.01$, *** $p < 0.001$.

(3) Structural Continuity

Given the continuity between administrative decision-making and governance implementation, the information interaction networks at these two levels were treated as co-occurring networks. The Quadratic Assignment Procedure (QAP) was employed to validate their structural correlation. To eliminate differences in node scope, analysis was confined to the subnetworks comprising governance entities and their relationships. Results indicate that, under both routine governance and emergency management scenarios, the network structures supporting administrative decision-making and governance implementation exhibit a statistically significant positive correlation, demonstrating structural continuity. See Table 3.

Table 3. Network Structural Correlation Between Decision-Making and Execution Levels.

Network	Net 2	Net 4
Net 1	0.78 ***	
Net 3		0.35 ***

Note: *** $p < 0.001$.

From a practical perspective, these findings suggest that digital government governance should not treat all actors and interaction links uniformly. Hub-dominant structures imply priority should be given to key departments and recurring interfaces. Self-similar structures support modular and reusable system development. The continuity between

decision-making and execution networks suggests that governance redesign can begin with decision-level hubs and their mapping to execution-level collaboration.

5. Adaptive Governance Methods for Digital Government Systems

5.1. Innovation Drivers of Governance Methods

5.1.1. Structural Attributes of Digital Government Information Interaction

Observing the topological structure of government information interaction networks reveals the following characteristic properties:

(1) Scalelessness and Heavy-Tailed Distribution

Cross-boundary information flows emerge organically through accumulated operational demands rather than predetermined planning. The network exhibits scale-free characteristics of incremental growth and preferential attachment amid seemingly random expansion, forming a distinctive structure dominated by concentrated nodes and hubs. Therefore, governance and system design should prioritize hub-aware resource allocation (e.g., standard interfaces and stable responsibilities for hub actors) rather than uniform, one-size-fits-all coordination.

(2) Fractal and Self-Similarity

The network exhibits a fractal-nested self-similar structure, particularly pronounced in emergency governance scenarios and at the governance execution level. This indicates that government information interaction largely operates independently of administrative institutional structures, exhibiting self-organizing characteristics. Therefore, modular components should be designed as replicable prototypes that can be recombined across scales, enabling self-organizing expansion without prespecifying all scenarios.

(3) “Decision-Execution” Synergy

The network achieves dynamic coordination of policy processes through structural linkages across the “decision-making-execution” layers, ensuring operational implementation. This highlights the leading role of core nodes at the decision-making level. Therefore, aligning governance with decision-level hubs can provide a practical entry point to coordinate execution-level collaboration while preserving local adaptability.

(4) Domain Spillover and Resilient Expansion

The network replicates information units through self-similar patterns and addresses the ambiguity of governance boundaries and task spillovers via scale invariance, demonstrating its capacity to adapt to context-driven operational development through self-replication. Therefore, boundary-spanning and spillover should be treated as normal conditions in system evolution, motivating scalable modules and nested coordination mechanisms rather than rigid boundary definitions.

5.1.2. Structural Consistency in Digital Government Systems

Currently, digital government systems in China primarily adopt two governance models: hierarchical centralized governance and planned collaborative governance, as shown in Tables 4 and 5. The hierarchical centralized model emphasizes bureaucratic hierarchy with clear responsibilities and centralized decision-making, suitable for scenarios with clear structures and stable requirements but challenging for cross-departmental collaboration and dynamic changes. The planned collaborative model relies on platform architecture design and governance entities with dominant resources. While it highlights coordinated organization and multi-stakeholder participation, it remains constrained by rigid rules, delayed feedback, and limited adaptability.

Table 4. Constituent Elements of Hierarchical Centralized Governance Models.

Hierarchical Centralized Governance		Element Characteristics	Existing Issues
Application Scenarios	User Positioning	Core role of competent authorities with passive participation from other entities	Lack of user orientation
	Environmental Characteristics	Clear structure and stable demand environment	
System Infrastructure	Data Flow	Highly centralized data with predominantly vertical information flow	Difficulty in customizing new cross-border business collaboration
	Business Process Flow	Emphasis on vertical business logic	
System Architecture	Architecture Design	Structure and functions coupled with administrative hierarchy	Inflexible system architecture with poor dynamic adaptability
	Scalability	Complex approval and development processes	
Governance Structure	Organizational Decision-Making	Highly centralized hierarchical division of labor	Governance entities lack autonomy, making it difficult to address issues with local adaptability
	Collaboration Mechanisms	Reliance on administrative directives and vertical hierarchical feedback channels	

Table 5. Constituent Elements of Planned Collaborative Governance Models.

Planned Collaborative Governance		Element Characteristics	Existing Issues
Application Scenarios	User Positioning	Enhanced horizontal collaboration	Difficulty in promptly capturing changes in the user environment
	Environmental Characteristics	Cross-departmental collaboration scenarios with clearly defined requirements	
System Infrastructure	Data Flow	Data flow enabled through standardized interfaces	Collaborative processes rely on predefined plans and data resources, lacking flexibility
	Business Process Flow	Predefined Business Processes	
System Architecture	Architecture Design	Platform-centric modular design	The master-slave relationship between platform and modules increases system expansion complexity
	Scalability	System expansion relies on platform resources and established rules	
Governance Structure	Organizational Decision-Making	Governance entities with dominant resource control	Excessively broad horizontal governance spans result in inefficiency
	Collaboration Mechanisms	Horizontal mechanisms such as joint meetings	

Although cross-boundary information flows in digital government lack micro-level regularity—where node importance and modularity defy unified description within the overall governmental framework—macro-level observation reveals a network topology exhibiting scale-free properties, fractal self-similarity, and highly interconnected decision-making and execution patterns. This reflects the dynamic evolution of systemic structures and intrinsic relationships [29]. Linking system architecture, governance structures, and the structural attributes of information interaction networks as core elements of adaptive governance in digital government facilitates alignment between the operational requirements of the holistic government and the governance system of information systems.

In this paper, “adaptive” refers to the capability of a digital government system to continuously reconfigure its system architecture and governance arrangements in response to context-driven changes in information practices (e.g., shifting actors, objectives, and boundary-spanning tasks), rather than relying on predetermined processes or a fixed hierarchy. The identification of adaptive governance methods follows a clear derivation path: (i) Section 4 extracts empirical interaction networks and summarizes their structural properties (e.g., hub-dominance, self-similarity, and decision–execution continuity); (ii) Section 5.1.2 uses these properties to diagnose why hierarchical centralized governance and planned collaborative governance become structurally misaligned under contextualization; and (iii) based on this diagnosed misfit, Section 5.3 formalizes the adaptive governance principles (GP1–GP4) and Section 5.4 further refines them into 11 falsifiable governance rules to guide dynamic alignment, on-demand modularization, and layered-nested coordination.

Tables 4 and 5 presents an analytical synthesis of the planned collaborative governance model. It is derived from three sources: the relevant literature on digital government governance, the dominant collaborative arrangements commonly observed in practice, and the structural diagnosis developed from the empirical findings of this study.

5.2. Vision for Adaptive Governance in Digital Government Systems

To adapt to diverse scenarios, digital government systems must enhance the autonomy, coordination, and dynamic adjustment capabilities of their components. We draw on the adaptive governance perspective, which emphasizes (i) responsiveness and learning under uncertainty, (ii) polycentric or multi-actor coordination instead of reliance on a single hierarchical controller, and (iii) maintaining governmental stability and accountability while adapting to change [18]. Based on adaptive governance principles, the overall structure should not rely on a single governing entity or administrative hierarchy, nor should it preset application scenarios or business processes. Instead, it should flexibly respond to contextual changes through self-organization. Its core values include:

- ① Adaptive Environment: The system promptly detects changes in the user environment to address government governance challenges;
- ② Flexible Business Reorganization: Distributed data processing and flexible integration facilitate customized business process reconfiguration;
- ③ Self-organizing architecture: Components coordinate autonomously, enabling seamless scalability;
- ④ Decentralized Collaboration: Governance entities enjoy ample autonomy to organize collaboration based on operational needs.

5.3. Adaptive Governance Framework for Digital Government Systems

The seminal work *The Essence of Information Systems Theory* [30] categorizes information systems theory into five types: analysis, explanation, prediction, explanation and prediction, and design and action. Among these, design and action theory focuses on “how to do,” establishing falsifiable principles and methods for solutions and governance processes [31]. As a design and action theory study, this paper proposes a self-organizing adaptive governance approach. It aims to standardize the architecture and governance structure of digital government systems, achieve decoupling from administrative systems and predetermined plans, dynamically respond to evolving scenarios in digital government information practices, and enable synchronous growth of systems and operations. Based on the classical framework proposed in “*The Essence of Information Systems Theory*,” the adaptive governance approach encompasses governance objectives, governance issues, core theories, and governance principles, as shown in Table 6.

Table 6. Theoretical Framework for Adaptive Governance in Digital Government Systems.

Governance Objective: Achieve structural alignment between IT and business operations in digital government information practices	
Governance Issues	Core Theory
GQ1: How to maintain consistency between IT and business? GQ2: How to enable self-organizing system growth? GQ3: What governance structure should be adopted to accommodate system growth?	-- Gain momentum for formal system adoption through enhanced structural coherence (IT alignment, complex network theory) -- Support self-organizing growth through the self-replicating nature of fractal systems (complex network theory, modularity theory) -- Align governance structures with modular system architectures (Modularity Theory)
Governance Principles:	GP1: Pursue dynamic structural coherence between systems and information interaction networks GP2: Modularize systems on demand GP3: Utilize self-similarity to achieve repetitive growth across different scales GP4: Construct a hierarchical nested governance structure
General Applicability: Suitable for cross-departmental, cross-domain, uncertain, and dynamically evolving digital city governance scenarios	

The core theory underpins the theoretical framework and guides the formulation of falsifiable governance principles. This paper centers on IT consistency, complex networks, and modularity theory: IT consistency provides a logical analytical starting point; complex

networks characterize the interactive structure of information practices through abstraction and retention of key features; modularity theory guides the development of bottom-up system architecture and governance structures. Governance principles are derived from the core theories through the following logical framework.

GQ1: How to maintain alignment between IT and business operations?

In cross-domain, uncertain, and dynamically evolving application scenarios, the complex structure of information interaction networks reflects the dynamic, cross-boundary information flow characteristics of digital government. Even when achieving alignment between IT and business operations proves challenging at the micro level, it remains possible to optimize system architecture and governance structures. This enables information systems and interaction networks to converge in structure and growth patterns, thereby achieving IT alignment at the macro level.

GQ2: How can systems achieve self-organizing growth?

The self-similarity of fractal networks provides a solution for self-organization in digital government systems. Unlike platform-centric planned collaboration models, modular components are generated and combined on demand. This approach begins by constructing a minimal prototype system, which is then reorganized, scaled up, or scaled down at different levels according to application needs, enabling the system's self-organizing growth.

GQ3: What governance structure should be adopted to accommodate system growth?

Centralized governance emphasizes control, while decentralized governance promotes collaboration. Given the multi-scale scalability of fractal information systems, a rule-based, hierarchical nested governance structure is adopted. Through top-down authorization mechanisms, this ensures synergistic alignment between governance mechanisms and system architecture.

5.4. Adaptive Governance Rules for Digital Government Systems

The aforementioned governance principles provide guidance for digital government systems to achieve orderly self-organization in complex environments. These principles are refined into a set of governance rules to manage and guide the generation and operation of system architecture and governance structures, as shown in Table 7. The following sections elaborate on the 11 governance rules and explain how they are derived from the core theory. Each rule presents a falsifiable statement. By examining compliance with the rules and their outcomes, the effectiveness of these rules and their theoretical foundations can be evaluated.

GR1: Treat the structural processes of information interaction networks as the basis for dynamic modularization of system architecture. Facing diverse and emergent demands, IT consistency should shift from static to dynamic. Information system architecture should be grounded in the macro-level structure of information interaction networks rather than relying on static relationships or micro-level functions, thereby achieving dynamic adaptation and optimization.

GR2: Employ formal systems rather than ad hoc approaches. While ad hoc solutions are prevalent, they disregard the integrity and standardization required by governance structures and information regulations, thereby undermining the institutional authority and normative efficacy of information system governance.

GR3: Treat every business function as a modular component. System modularization provides foundational support for functional reorganization and self-replication. Each component's interface design must inherently incorporate mechanisms for combination, ensuring loose coupling between components.

GR4: Deploy small-scale systems on demand, avoiding reliance on large platforms. Platform-based architectures often create power constraints, manifesting as externally

organized systems. The self-organizing vitality of digital government primarily stems from the practical needs of governance actors and subjects.

Table 7. Adaptive Governance Rules for Digital Government Systems.

Governance Issue	Theoretical Elements	Governance Principle	Governance Rule
GQ1: How to maintain alignment between IT and business?	TE1: Design an information system architecture that converges with the structure of information interaction networks	GP1: Pursue dynamic structural alignment between information system architecture, governance structures, and information practices	GR1: Use the macro-structural processes of information interaction networks as the basis for dynamic modularization of information system architecture GR2: Employ formal systems rather than ad hoc approaches
GQ2: How to enable self-organizing system growth?	TE2: Constructing a Fractal Modular System Architecture	GP2: Modularizing systems on demand GP3: Leveraging Network Self-Similarity for Self-Replicating Growth of Information Systems Across Scales	GR3: Treating each business function as a modular component GR4: Deploying Small-Scale Systems on Demand Instead of Large Platforms GR5: Continuously Develop Components During Operation GR6: Construct replicable, scalable component prototypes GR7: Determine prototype scale of system modules based on fractal dimension, or derive system self-replication scale from prototype scale GR8: Deploy universal components for governance entities and objects with cumulative relational advantages
GQ3: What governance structure should be adopted to accommodate system growth?	TE3: Aligning governance structures with system architecture at the macro level	GP4: Construct a hierarchical nested governance structure to adapt to fractal networks	GR9: Conduct network governance through hubs within heterogeneous groups, implementing centralized governance led by hubs within these groups GR10: Identify key actors and core modules in administrative decision-making to activate governance networks at the execution level GR11: Avoid establishing temporary governance structures solely to address specific collaborative needs

GR5: Continuously develop components during operation. Unlike typical, predictable event management approaches, the constantly emerging business and information demands in digital government governance are often difficult to precisely define during initial system development. Therefore, a development mechanism capable of dynamically responding to changing demands is required.

GR6: Construct replicable, scalable component prototypes. Components and their connections form the fractal elements of digital government information systems. These fractal elements combine to create larger-scale fractal structures, which gain endogenous growth momentum through continuous reorganization.

GR7: Determine prototype scales for system modules based on fractal dimensions, or derive the scale of system self-replication from prototype scales. Despite the inherent ambiguity in digital government governance boundaries, system construction must maintain clear boundaries. Only by adhering to the scale relationship between the system's potential scale and component prototypes can free scaling be achieved.

GR8: Deploy generic components for governance entities and objects possessing cumulative relational advantages. Given the shifting power-law characteristics of information interaction networks, actors with cumulative relational advantages should assume more prominent and stable roles in information system deployment, making them suitable for standardized generic components.

GR9: Conduct network governance through hubs within heterogeneous groups, implementing centralized governance led by hubs within these groups. Core governance

entities should consist of hubs, which may operate at the same level or across multiple levels depending on application scenarios.

GR10: Identify key actors and core modules in administrative decision-making to activate the network at the governance execution level. To ensure continuity in digital government governance, the information interaction network at the execution level must align structurally with the network at the decision-making level. Therefore, the governance structure should first align with the network structure at the decision-making level while maintaining adaptability and flexibility.

GR11: Avoid establishing temporary governance structures solely to address specific collaborative needs. While emphasizing the flexibility of system modularity, the governance structure itself should maintain relative stability to prevent ad hoc frameworks from hindering the holistic evolution of digital government information systems.

6. Conclusions

6.1. Research Conclusions

This paper identifies the structural patterns of government information interaction in typical governance scenarios and analyzes their governance implications. Based on these empirical findings, it further develops a testable adaptive governance approach to support the sustainable evolution of digital government systems. Based on this, the paper justifies the design logic of its framework and proposes a self-organizing adaptive governance approach. This approach emphasizes dynamic alignment between system architecture and governance structure, as well as on-demand modular and layered nested governance mechanisms. Subsequently, the paper further refines the governance mechanisms into 11 falsifiable governance rules, thereby providing testable propositions and concrete paths for subsequent empirical validation, rather than remaining at a descriptive discussion level. Unlike traditional methods that promote “system-business” alignment through structured techniques, adaptive governance is based on bottom-up information practices.

In this sense, sustainability is not treated as an external normative goal, but as an emergent property of adaptive structural alignment in digital government systems. By shifting the focus from short-term optimization to adaptive structural alignment, the proposed governance framework thus contributes to the sustainable evolution of digital government systems. It resolves the tension between centralized governance and structural rigidity, providing sustained adaptability for cross-departmental and cross-domain application expansion in digital government.

6.2. Limitations and Future Research

This study has several limitations that should be acknowledged, specifically as follows:

(1) Our empirical evidence is based on a limited set of scenarios and policy corpora, which may not fully capture the diversity of information practices across regions, sectors, and stages of digital government development.

(2) The construction of the decision-making network relies on the co-occurrence of jointly released information. Although this is a typical indicator of interaction among government departments, it may overlook information interactions through other channels, resulting in a lack of comprehensiveness.

(3) While the proposed governance principles and rules are derived from observed patterns, they have not yet been systematically tested across multiple independent cases or validated against ground-truth operational data.

Therefore, future research can start from the following perspectives: First, future studies may include a broader range of governance scenarios and a more extensive corpus of policy texts drawn from different regions, departments, and stages of digital government

development. This would broaden the research scope, enable systematic cross-context comparisons, and improve the generalizability of the network patterns identified in this study. Second, to enhance the completeness of interaction measurement, subsequent research can compare co-occurrence ties derived from jointly issued policies with data capturing other interaction channels. This would help determine whether the inferred decision-making network structure remains stable across alternative interaction measures. Third, the governance principles and rules proposed in this paper can be operationalized into measurable indicators and validated through empirical cases. Doing so would allow a more rigorous assessment of their predictive performance and boundary conditions, thereby further refining the adaptive governance framework.

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