Innovation Economics and Management Research (IEMR), Volume 11, Issue 2, 2026. ISSN: 2949-1304
Proceedings of The 7th International Conference on Management, Economy and Law (ICMEL 2026)

Multi-level Structure and Functional Analysis of the Water Environment Collaborative Governance Network in the Yangtze River Delta

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ABSTRACT
This article focuses on the criss-crossing power relations and interaction patterns, and analyzes how vertical bureaucratic authority and horizontal cross-border dependence couple to form a complex governance structure map. The analysis shows that the network improves the efficiency of environmental governance through cross-domain integration of resources, negotiation and balance of interest conflicts and iterative adaptation of institutional supply. The analysis also reveals the risk of information transmission attenuation and cooperation burnout that may be caused by structural rigidity. Based on this, the function repair path based on system resilience is proposed, and the importance of enhancing node redundancy and optimizing contract constraint mechanism is emphasized. The conclusion shows that it is an inevitable trend to go beyond the traditional single administrative control and turn to network collaboration. This theoretical explanation not only clarifies the operating mechanism of regional water environment governance, but also provides a solid logical reference for formulating more forward-looking and inclusive policy programs. This is helpful to promote the modernization transformation of ecological environment governance system under the background of Yangtze River Delta integration.

Keywords: *Yangtze River Delta, Water environment, Collaborative governance, Collaborative network, Multi-level structure.*

1. INTRODUCTION

As typical public goods, water environment has obvious characteristics of cross-border mobility and ecosystem integrity. The traditional administrative jurisdiction system often presents the characteristics of spatial fragmentation, which restricts the ecological security of the basin [1]. The Yangtze River Delta is one of the most active and open regions in China. Its high-density urbanization and industrialization make the water environment pressure increase sharply, and also give birth to more complex cross-border governance needs [2]. Under this macro background, it is difficult to adapt to the complex and changeable environmental governance challenges by relying solely on bureaucratic administrative instruction control [3].

Although academic circles have paid a lot of attention to regional cooperation, the existing research mostly focuses on the interpretation of policy texts or the experience summary of specific cooperation mechanisms [4]. The actual efficiency of governance network is not generated out of thin air, but rooted in its multi-level structure coupling relationship [5]. If we can't clarify the boundary of power and responsibility allocation, vertical and horizontal connection modes and their interaction mechanisms of different levels of subjects in the network, it will be difficult to truly understand the overall performance source of regional water environment governance [6]. For this reason, it is particularly critical to construct a theoretical analysis framework that goes beyond empirical description and explore how structure determines function.

This article focuses on the multi-level structure and function analysis of the water environment cooperative governance network in the Yangtze River Delta. This article attempts to construct an explanatory theoretical model to explore how vertical administrative hierarchy authority and

horizontal cross-border interactive dependence interweave into a complex governance network. With the help of this pure theoretical dimension, it is expected to reveal the deep operating mechanism and logical tension behind regional collaborative governance, and provide solid theoretical support for solving the structural contradiction between administrative division and river basin planning.

2. STRUCTURAL ATLAS AND HIERARCHICAL CHARACTERISTICS

2.1 Vertical Hierarchy of Power and Responsibility Allocation Logic

In the theoretical model of regional cooperative governance, the vertical hierarchical structure constitutes the basic skeleton of the network. Its core lies in the distribution of rights and responsibilities between the central government and local governments and between the upper and lower levels within local governments. This vertical chain is not a simple instruction transmission process, but a responsibility transmission mechanism based on legal authorization and administrative entrustment [7]. In this dimension, high-level subjects mainly undertake the functions of rule-making, macro-planning, supervision and assessment, while low-level subjects focus on specific implementation and feedback. Bureaucratic authority ensures the unity of governance objectives, but it also leads to the attenuation of information transmission and the potential lack of incentive compatibility. Based on this reason, the optimization direction of vertical structure lies in how to give more local discretionary space while maintaining administrative control.

2.2 Main Body Connection Mode of Horizontal Dimension

The horizontal dimension reveals the spatial connection mode across administrative boundaries, which is mainly manifested in the cooperation and interaction between governments at the same level in different administrative divisions. This horizontal relationship broke through the closed management in a single jurisdiction and turned to build a community of interests based on the natural attributes of the basin [8]. Theoretically, horizontal connection depends on negotiation mechanism, contract spirit and resource sharing commitment, and the subjects show obvious interdependence characteristics. Because of the external spillover effect of water pollution, the governance decisions of any two adjacent areas will have an impact on each other. This strong correlation forces all parties to establish a normalized dialogue channel to avoid zero-sum game [9]. The horizontal network includes formal cooperation agreements between governments, as well as technology transfer involving market participants and supervision and assessment involving social organizations. In this way, a flat interactive pattern of multiple subjects is formed, which effectively makes up for the blind spot of vertical management.

2.3 Interlaced Composite Network Architecture

When the vertical authority chain and the horizontal interactive network are superimposed, a complex composite governance structure map is formed. This architecture shows the characteristics of multi-node and multi-level in the sense of topology. Among them, the key nodes often assume the coordination function of the hub, rather than the simple command publisher. Figure 1 presents this abstract structure more intuitively. The nodes in the composite structure are not static, but dynamically adjusted with the change of governance issues. It requires the governance subject to have stronger adaptability and toughness to cope with the ever-evolving ecological environment challenges.

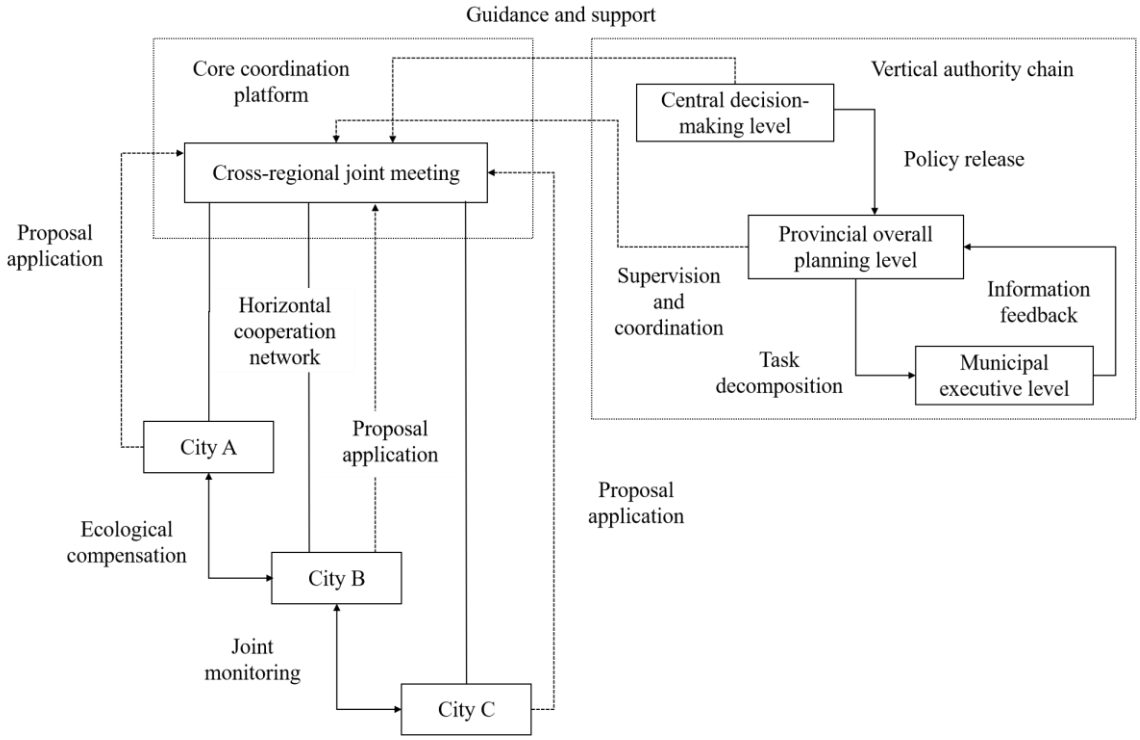


Figure 1 Network structure of water environment management in Yangtze River Delta.

3. FUNCTIONAL MECHANISM AND OPERATIONAL LOGIC

3.1 Integration and Allocation Function of Resource Flow

The core efficiency of the regional water environment cooperative governance network is firstly reflected in the ability to integrate various key resources. This ability depends on the trust relationship and contract constraints between different nodes in the multi-level structure. Theoretically, the network integrates scattered local financial investment, professional and technical personnel and environmental monitoring data into a unified deployment platform [10]. Higher-level governments usually provide start-up funds and policy endorsements, while grass-roots implementation units contribute specific information feedback and technical solutions. Through the dual channels of vertical instruction and horizontal negotiation, the two sides realized the approach of resource flow to the optimal solution. This process reduces transaction costs through standardized interface protocols and transparent information disclosure mechanisms. The resulting resource allocation advantage has improved the efficiency of capital use and strengthened the ability of the governance system to deal with sudden environmental incidents.

3.2 The Function of Negotiating and Balancing Conflicts of Interest

Another key function of the collaborative network is to build an effective interest coordination mechanism to resolve conflicts caused by cross-border externalities. Due to the natural tension between the integrity of river basin ecosystem and the division of administrative jurisdiction, the protection behavior of upstream areas often leads to the positive externalities of downstream areas, and vice versa. In order to maintain the stable operation of the network, the main structure of governance has established a set of institutionalized consultation procedures including ecological compensation, joint law enforcement and responsibility sharing (Table 1). These mechanisms clarify the specific rights and responsibilities of all parties in pollution sharing, pollution control investment and income acquisition, and transform the abstract willingness to cooperate into operational norms of behavior.

Table 1. Collaborative Governance Mechanism of Yangtze River Delta Water Environment

Mechanism Type	Structural Foundation	Expected Functional Output	Scope of Application
Horizontal Fiscal Transfer Payment	A Covenant at Intergovernmental level	Provide Financial Compensation for Stakeholders with Damaged Interests	Only Water Quality Assessment Results for Cross-border Sections
Data Sharing Cloud Platform	Interconnection of Municipal Information Centers	Eliminate Decision Bias Due to Information Asymmetry	EInformation Not Related to Trade Secrets or Security
Joint Cruise Law Enforcement Team	Cross-regional Joint Action Group	RESIST jurisdictional conflicts and avoiding penalties	Confined to Cross-regional Border Water Areas
Expert Advisory Committee	Embedded Third-party Think Tanks	Provide Scientific Decision Support and technical appraisal of the dispute	No Final Administrative Adjudicative Effect

3.3 Innovation and Adaptation Function of Institutional Supply

The strong institutional innovation vitality of the collaborative network can keep it in a state of adaptation under uncertain environmental changes. The traditional bureaucratic system often leads to slow system reform because of too many levels, while the networked structure can quickly produce new governance models through the exploration of multiple parallel nodes. Once the successful experience of a node is proved to be effective, the communication mechanism in the network will accelerate the diffusion and assimilation of the experience to other nodes. This point-to-point innovative radiation logic enables regional water environmental governance to continuously absorb emerging environmental management technologies and social organization participation methods. For this reason, the effective function depends on the static structural design, but also on the continuous learning, iterative updating and agile response ability to external environmental changes within the network.

4. VALUE EXAMINATION AND PATH DEDUCTION

The structural nodes of governance network are generally structurally failed and leads to the functional alienation. When vertical instructions cannot be effectively transformed into horizontal actions, resource allocation will be fragmented; when the horizontal coordination mechanism lacks authoritative support, the conflict of interests will be deadlocked. Table 2 takes structural defects as input variables and functional repair as the target output, and points out the theoretical countermeasures that should be taken in different risk situations. These paths are not simple policy suggestions, but the redesign of governance ecology based on the principle of network dynamics. By improving the substitutability of network nodes and the redundancy of connections, the stability of the system under external shocks can be enhanced, and the continuous capacity evolution of water environment collaborative governance can be ensured in the dynamic changing environment.

Table 2. Risks and Recovery Theory of Collaborative Governance

Structural Risk Type	Functional Alienation Manifestation	Resilience Restoration Path	Expected Effect
Vertical Hierarchy Breakpoint	Policy Transmission Attenuation, Implementation Distortion	Build Direct Feedback Channels and Specialized Supervisory Teams	Resynchronize the Execution of Instructions
Horizontal Connection Weakening	Cross-border Interest Spillover, Free-riding Behavior	Periodically Work with Third Parties and Dynamic Payments	Improve the Equity of Cost Sharing
Excessively High Node Dependence	Choke Hold on Major Hubs Results in Network Standstill	Develop Multi-node Backup Nodes and Replacement Mechanism	Improve the System's Anti-disruption Capability
Institutional Supply Lag	Slow Response to Uncertainty	Use Agile Test Error Zones & Innovation Tolerance Clauses	Increase the Speed of Enumeration of New Tools

5. CONCLUSION

This article discusses the multi-level structure and function of the water environment cooperative governance network in the Yangtze River Delta. The governance network is not a simple administrative superposition, but presents a composite feature of interweaving vertical authority chain and horizontal interest community. The essence of network function is highly dependent on specific operating mechanisms, including cross-domain efficient flow of financial funds and information resources, interest balance mechanism based on ecological compensation and agile iterative institutional supply system. These mechanisms together constitute the endogenous power of the network to resist external environmental shocks and internal game risks. Without effective toughness design and dynamic adjustment, the governance network will easily face the dilemma of decreasing efficiency of execution deviation or cooperation burnout. The functional restoration path based on resilience theory emphasizes the key role of institutionalized consultation platform and third-party independent assessment mechanism in breaking administrative barriers. Future research can further pay attention to the influence of the deep embedding of digital technology on the reshaping of network topology, and how to transform abstract theoretical deduction into a quantifiable monitoring governance performance index system. In addition, the complementary role of informal institutions should be fully considered in policy design to reduce coordination costs.

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