

Institutional Barriers and Technology-Enabled Pathways for Regional Collaboration Among Disease Control Agencies in China

Zhang Min

Chongqing Shapingba District Center for Disease Control and Prevention

Li Jun

Chongqing Shapingba District Center for Disease Control and Prevention

Hu Bin

Chongqing Shapingba District Center for Disease Control and Prevention

Zhang Chunhua

Chongqing Center for Disease Control and Prevention

Yang Tong

850084969@qq.com

Chongqing Shapingba District Center for Disease Control and Prevention

Research Article

Keywords: Disease prevention and control, Regional collaboration, Institutional barriers, Technology-enabled solutions, Public health governance

Posted Date: June 19th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9952444/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at BMC Public Health on August 1st, 2026.
See the published version at <https://doi.org/10.1186/s12889-026-28807-x>.

Abstract

Background

Regional collaboration among disease prevention and control (CDC) agencies is critical for public health governance in China. However, institutional and technical barriers hinder its effectiveness.

Objective

To identify key institutional barriers to regional CDC collaboration in China and explore technology-enabled pathways to overcome them.

Methods

We conducted a policy document analysis (1998–2025), comparative case studies of three regional models (Yangtze River Delta, Beijing-Tianjin-Hebei, Chengdu-Chongqing), and an international comparison (EU, WHO Europe, US), guided by an institution–technology dual-dimensional framework.

Results

China has established a preliminary policy framework for CDC collaboration, but three core barriers persist: vertical disconnects in authority and responsibility; spatial resource imbalances (eastern vs. western per capita funding gap: 2.3-fold); and fragmentation of technical standards, which has led to non-interoperable information systems and delayed cross-regional response.

Conclusions

A dual-track synergy mechanism combining institutional redesign and technology-enabled solutions is needed. Key priorities include tiered coordination systems, cross-regional compensation mechanisms, unified technical standards, and adaptive digital infrastructure.

1 Introduction

Amid evolving global public health risks, the coordinated development of regional CDC has become central to improving public health governance ^[1]. Since the 2003 SARS outbreak, reforms of China's CDC system have deepened progressively, and the COVID-19 pandemic exposed shortcomings in cross-regional joint prevention and control, further accelerating innovation in collaborative mechanisms. In 2023, the State Council issued the "Guiding Opinions on Promoting High-Quality Development of the Disease Prevention and Control Sector," which for the first time proposed at the national level the

establishment of a “modern disease control system characterized by graded and tiered structures and regional coordination.” This signals a shift in China’s regional disease control coordination from emergency response to institutionalized development ^[2]. However, in reform practice, institutional barriers have universally constrained the effectiveness of collaboration. For instance, administrative divisions have led to inefficient allocation and coordination of regional resources; information silos resulting from differing technical standards have hindered cross-regional information exchange; and the inertia in collaboration stemming from ambiguous responsibilities has induced diffusion of responsibility and interagency friction when addressing public health issues ^[3].

Accordingly, this study integrates institutional change theory and technology empowerment theory to construct an “institution-technology” dual-dimensional analytical framework comprising three core dimensions. The first is the institutional environment dimension, encompassing formal rules derived from policy texts and informal constraints stemming from organizational culture; the second is the coordination structure dimension, focusing on the allocation of authority and responsibility across vertical hierarchical levels and the mechanisms of resource flow between horizontal regions. Third is the technological empowerment dimension, which emphasizes pathways for overcoming institutional barriers through the application of digital technologies. By employing this three-dimensional “institution-technology” dual-analysis framework to systematically analyze the evolutionary logic and practical shortcomings of regional disease control collaboration in China, this study lays a solid theoretical foundation for optimizing the regional disease control collaborative governance system.

This framework guides our investigation of three core research questions: (1) What major institutional barriers constrain regional CDC collaboration in China? (2) How do three representative regional collaboration models differ in their mechanisms and outcomes? (3) How can technology-enabled pathways be designed to work synergistically with institutional innovation?

2 Methods

Study Design: This study employed a multi-method qualitative design that integrated policy document analysis, comparative case study, and international comparative analysis, guided by an “institution–technology” dual-dimensional framework.

Data Sources: Policy documents: 24 national-level documents (1998–2025) from the State Council, National Disease Control and Prevention Administration, and National Health Commission.

Case study data: Three models selected based on geographic diversity, mechanism variation (standardization, law enforcement, policy-driven), and data availability (2018–2025).

International data: EU (European Health Union, ECDC), WHO European Region (Healthy Cities Network, HMF), US (FEMA, SNS, PHSA Section 319).

Analytical Phases: Policy evolution analysis: Thematic coding and phase categorization (Capacity-Building 1998–2015; Mechanism Exploration 2016–2020; System Consolidation 2021–present).

Comparative case analysis: Cross-model comparison across governance structure, resource allocation, technical interoperability, and outcomes.

International comparative analysis: Four-dimension comparison (governance, legal basis, technical integration, resource allocation) with transferability assessment.

Quality Assurance: Two authors independently coded all policy documents and case findings; discrepancies were resolved through discussion.

Limitations: This study relies on secondary data (policy documents, published literature, and government reports) and did not collect primary data through interviews or surveys. The cross-sectional design cannot capture dynamic changes in collaboration effectiveness over time.

3 Policy Evolution and Practical Models of Collaborative Development Among Regional Disease Control Institutions in China

3.1 The Evolutionary Trajectory of the Policy Framework

The formation and evolution of China's policy system for regional disease control collaboration have undergone three significant phases, reflecting a shift in governance logic from emergency response to institutional restructuring.

Phase I: Capacity-Building Period (1998–2015). In 1998, the Shanghai Center for Disease Control and Prevention was established as the first CDC in China. In 2001, the General Office of the Ministry of Health issued the "Guiding Opinions on the Reform of the Disease Prevention and Control System," marking the initial formation of China's disease control system centered on a four-tier network of disease control centers. The 2003 SARS outbreak served as a major turning point in the development of China's disease control system, directly accelerating the progress of reforms toward vertical management. The "Several Provisions on the Construction of the Disease Prevention and Control System," issued in 2005, further clarified the seven core functions of disease prevention and control centers and emphasized strengthening foundational capabilities such as epidemiological investigations and laboratory testing. During this period, although local regions actively explored new approaches, policy evolution exhibited characteristics of fragmented innovation, and systematic institutional integration had not yet been achieved.

Phase II: Mechanism Exploration Period (2016–2020). The "Healthy China 2030" Planning Outline, released in 2016, first proposed "establishing a regional public health collaboration mechanism," charting a new course for the coordinated development of regional disease control and prevention. The "Outline of the Yangtze River Delta Regional Integration Development Plan," released in 2019, introduced practical

standardization initiatives, achieving mutual recognition among regions across nine key areas, including infectious disease reporting and laboratory quality control. During this phase, the focus of public health policy gradually shifted toward institutional innovation. However, due to fiscal decentralization and administrative barriers, regional development imbalances became increasingly prominent, which constrained the effective implementation and further advancement of the collaborative mechanisms.

Phase Ⅱ: System Consolidation (2021–Present). The formal establishment of the National Center for Disease Control and Prevention in 2021 laid the foundation for administrative reform in the implementation of disease control reform policies. Subsequently, disease control centers at all levels, through administrative delegation and resource integration, jointly advanced a new phase of institutionalizing and operationalizing regional disease control collaboration. In 2023, the State Council issued the "Guiding Opinions on Promoting High-Quality Development of the Disease Prevention and Control Sector," which established a groundbreaking new framework of "Six Core Capabilities + Regional Collaboration" and explicitly required the "establishment of National Regional Public Health Centers based on high-level provincial disease control centers." The introduction of this policy marked a crucial step forward in the top-level design of regional disease control collaboration. The "National Disease Prevention and Control Action Plan," released in 2024, further detailed tasks for the joint construction of infrastructure such as regional laboratory networks and talent training bases, providing specific guidance at the operational level.

3.2 Typical Models and Practical Outcomes of Regional Collaboration

3.2.1 The Yangtze River Delta “Standardization Collaboration” Model

The Yangtze River Delta region has broken down technical barriers through a mutual recognition mechanism for standards. It took the lead in establishing the nation’s first regional health standards committee, achieving significant breakthroughs in multiple key areas. In the realm of data interoperability, a unified direct reporting system for infectious diseases was established, which increased the timeliness rate of infectious disease reporting to 98.5% ^[4]. In terms of resource sharing, Shanghai, Jiangsu, Zhejiang, and Anhui have achieved mutual recognition of laboratory test results, reducing duplicate testing within the region by 30% ^[5]. Regarding joint talent development, a joint training program for epidemiology professionals was formulated and implemented, cumulatively training 1,200 key personnel ^[6]. Relying on a developed economic foundation and homogeneous governance standards, this model faces structural limitations during its promotion due to insufficient participation from less developed regions, which, to some extent, restricts its broader dissemination and application.

3.2.2 The "Law Enforcement Collaboration" Model in the Beijing-Tianjin-Hebei Region

The Beijing-Tianjin-Hebei region has established a law enforcement collaboration model centered on “joint prevention and control.” In 2018, the six localities in the region signed a cooperation agreement on the coordinated development of health and family planning supervision and law enforcement ^[7], marking a major initiative in regional collaboration. In recent years, the Beijing-Tianjin-Hebei region has relied on information-sharing and emergency consultation mechanisms to achieve synchronized decision-making through frequent communication and data exchange; leveraged risk management and law enforcement coordination mechanisms to conduct joint epidemiological investigations, personnel searches, and unified operations, thereby effectively enhancing emergency response efficiency; and provided institutional and organizational safeguards for coordinated actions through cross-regional cooperation agreements and interdepartmental coordination ^[8]. In responding to major public health emergencies such as the COVID-19 pandemic, this model has effectively prevented the cross-regional spread of the epidemic ^[9]. Research indicates that while institutional joint actions in the field of public health emergencies are relatively extensive across the three regions of Beijing, Tianjin, and Hebei, the depth of regional policy coordination still needs to be further strengthened ^[10].

3.2.3 The “Policy-Driven” Model in the Chengdu-Chongqing Region

The Chengdu-Chongqing region has established a multi-tiered cooperation system guided by a “policy-driven” approach. This system is anchored by the “Outline of the Construction Plan for the Chengdu-Chongqing Dual-City Economic Circle” as its top-level design and is implemented through specific measures such as district-to-district partnerships and alliances among neighboring regions ^[11]. For example, the Health Commissions of Chengdu and Chongqing have jointly released the “Ten Initiatives for Integrated Health Development” to promote “joint planning and joint team building.” ^[12] Hechuan District and Changshou District in Chongqing, along with Guang’an City in Sichuan Province, have committed to conducting annual cross-regional emergency drills and issuing joint risk assessment reports ^[13]. At the level of coordinated law enforcement, Wanzhou District and Kaizhou District in Chongqing, together with Dazhou City in Sichuan Province, have achieved the integration of law enforcement and legal education through mixed teams of health law enforcement officers and unified standards ^[14]. In the areas of technical coordination and service innovation, regional immunization program services have been upgraded, and the integration of primary healthcare and disease prevention has been promoted through joint training on “vaccine prescribing” ^[15]. These practices demonstrate that the Chengdu-Chongqing region is systematically advancing the integrated development of regional disease control through mutual recognition of policies, resource sharing, synchronized law enforcement, and coordinated services, with a commitment to building a more robust public health safety barrier for residents.

A comparison of the three types of collaboration models is presented in Table 1.

Table 1
Comparison of Regional Collaboration Models (2018–2025)

Model Type	Representative Region	Core Mechanism	Key Outcomes
Standardization Collaboration	Yangtze River Delta	Mutual Recognition of Technical Standards	Infectious disease reporting timeliness: 98.5%; duplicate testing reduced by 30%; 1,200 epidemiologists trained jointly
Law Enforcement Cooperation	Beijing-Tianjin-Hebei	Cross-regional Joint Prevention and Control	Improved emergency response efficiency; prevented cross-regional epidemic spread
Policy-Driven	Chengdu-Chongqing	Multi-level Policy-Driven Cooperation	Systematic enhancement across governance structures, risk management, and public services, e.g., joint risk assessments conducted annually

3.3 Summary of Model Characteristics

The three models differ across four dimensions. Institutionally, the Yangtze River Delta relies on standardization agreements among economically homogeneous regions; Beijing–Tianjin–Hebei uses law enforcement agreements focused on emergency response; Chengdu–Chongqing adopts a multi-level policy-driven framework that integrates governance, risk management, and services but depends on sustained political commitment. In coordination mechanisms, all have moved beyond ad hoc collaboration, yet legal formalization varies. In resource integration, the Yangtze River Delta leads (30% reduction in duplicate testing, 1,200 epidemiologists trained), while others limit sharing to emergencies. In technological dependency, the Delta’s data system achieves 98.5% reporting timeliness; other regions lag in interoperability. Thus, no single model fits all; collaboration mechanisms must be tailored to regional context.

4 In-Depth Analysis of Institutional Barriers: Based on a Multi-Dimensional Evaluation Framework

Through systematic policy text analysis and field research, we identified three core institutional barriers that constrain the coordinated development of regional disease control agencies.

4.1 Vertical Disconnect in the Allocation of Powers and Responsibilities

Within the disease control system, a structural contradiction between “weakened vertical management” and “strengthened local responsibility” persists, hindering regional disease control collaboration. First, there are policy conflicts: although provincial disease control centers bear important regional guidance functions, personnel and financial authority still reside with local governments, resulting in a lack of

statutory authorization and necessary enforcement power for cross-regional collaboration ^[16]). Second, there is a misalignment in incentive mechanisms. The current performance evaluation system uses administrative divisions as its basic unit; however, cross-regional collaboration requires additional resource allocation without corresponding evaluation incentives, which results in municipal CDCs lacking sufficient intrinsic motivation when engaging in such collaboration ^[17]. Third, there is a legal vacuum: the Law on the Prevention and Control of Infectious Diseases does not clearly define the allocation of authority and responsibility in cross-regional collaboration, leading to a high likelihood of responsibility shifting during emergency response.

Impact on collaborative governance: These vertical disconnects produce three specific consequences: (1) command chain rupture during joint emergency response; (2) weak intrinsic motivation for local participation due to misaligned performance incentives; and (3) responsibility shifting during cross-jurisdictional outbreaks, as no legal framework defines accountability.

4.2 Spatial Imbalances in Resource Allocation

The allocation of regional disease control resources exhibits gradient differentiation. Fiscal decentralization, regional development disparities, and institutional design flaws jointly produce this spatial imbalance. The “Matthew Effect” triggered by regional disparities is particularly evident in three aspects. First, there is a significant disparity in fiscal investment. Data from 2024 shows that per capita funding for provincial-level disease control centers in the eastern region is 2.3 times that of the western region, and the gap in the number of high-end devices reaches as high as 4.5 times ^[18], which directly impacts the service capacity of disease control institutions across different regions. Second, a talent gap has emerged: in central and western provinces, the proportion of personnel holding senior professional titles is less than 15%, and the annual attrition rate reaches 8.7% (with most talent flowing to the Yangtze River Delta and Pearl River Delta regions) ^[19], leading to issues of “brain drain” and “intergenerational decline in capabilities.” Third, there is a mismatch between facility allocation and demand. In the eastern regions, due to high population density and frequent interprovincial mobility, demand for public health services is more concentrated; whereas in the western regions, with low population density and a vast geographical spread, place greater emphasis on geographic accessibility of services. Currently, the spatial distribution of high-quality healthcare resources in China remains uneven. For example, national regional public health centers are primarily concentrated in the Yangtze River Delta and Pearl River Delta regions, with none yet established in the western regions. This situation reflects, and may exacerbate, the structural contradiction between the allocation of public health resources and actual demand. Therefore, facility planning must fully account for regional disparities and optimize resource allocation to enhance the equity and efficiency of public health services.

Impact on collaborative governance: Spatial resource imbalances produce three consequences. First, unequal starting points—eastern CDCs dominate, turning collaboration into one-way technical assistance. Second, talent outflows from western regions create an “intergenerational capability gap,” hindering absorption of transferred resources. Third, supply–demand mismatches—eastern regions

need concentrated services for dense populations; western regions require geographic accessibility. Current resource distribution fails to address this structural difference, undermining both equity and effectiveness.

4.3 Fragmentation of Technical Standards

Data silos and inconsistent protocols undermine the efficiency of cross-regional CDC coordination. First is the phenomenon of system silos: from national, provincial, and municipal levels down to district and county-level disease control centers and health administrative departments, each often maintains its own independent system for direct reporting of infectious diseases, immunization programs, and health supervision. The lack of effective information-sharing and communication mechanisms between health departments at different levels leads to delays, distortion, or even interruptions in the vertical transmission of information^[20]. Second is the issue of divergent standards. Different information systems employ distinct data structures and communication protocols, adhering to varying technical standards. When data access is required across systems or departments, differences in technical standards make this difficult to achieve. Internationally, a series of standards such as HL7 (Health Level Seven) and FHIR (Fast Healthcare Interoperability Resources) have long been developed^[21], and some regions and institutions in China have adopted them; however, it remains difficult to assess whether these standards are widely and strictly adhered to or uniformly implemented. Finally, there are authentication barriers. During the COVID-19 pandemic, various provinces and cities independently developed health code systems, requiring users to download multiple apps or mini-programs and repeatedly undergo identity verification in order to “show their codes” in different regions—a clear manifestation of regional data barriers.

Impact on collaborative governance: Technical fragmentation causes three problems. First, the “last mile” of information sharing remains blocked—data exchange often relies on manual processes, causing delays. Second, response delays during cross-regional outbreaks—lack of near-real-time data sharing leads to late warnings. Third, interoperability costs become an invisible barrier—high technical investment offsets the benefits of institutional collaboration, reducing partners’ willingness to cooperate.

5. Lessons from International Experience: A Comparison of Diverse Models of Collaborative Governance

Developed countries have established relatively mature practices in building regional disease control coordination mechanisms, with the core elements lying in institutionalized collaboration, resource integration, and technological empowerment, which hold significant reference value for China.

5.1 The EU’s “Multi-level Governance” Model

The EU has established the European Health Union (EHU) through a strategy of “broad integration”^[22]. First, the EU innovated its governance structure by establishing the Health Emergency Response Authority (HERA) as a supranational coordinating body. Decision-making authority is shared between the

European Commission and member states, forming a dual-track governance model of “supranational guidance and national implementation.” Second, it utilizes legal coordination tools; through the implementation of the Cross-Border Healthcare Directive (Directive 2011/24/EU), member states are required to mutually recognize medical qualifications and share electronic health records. Third, a path for technological integration: The European Centre for Disease Prevention and Control (ECDC) has established a unified epidemic risk assessment model. The core strength of this model lies in its legally grounded coordination mechanism; however, its effective operation relies heavily on an institutionalized regional alliance framework, and its applicability to highly heterogeneous regions is limited.

5.2 WHO Regional Partnership Mechanisms

The WHO Regional Office for Europe promotes local collaboration ^{through} the “Healthy Cities Network” ^[23]. First is the partnership structure, which establishes a “roundtable” mechanism involving governments, professional institutions, and community organizations to ensure the integration of diverse stakeholder interests. Second is the standardized toolkit, which involves the development of a unified Health Monitoring Framework (HMF) covering 53 core indicators, including disease profiles and social determinants ^[24]. Third, a capacity-building strategy involves establishing regional training centers that train an average of 1,200 professionals from low- and middle-income countries annually ^[25]. This model excels in inclusive governance but faces challenges regarding financial sustainability, as it relies primarily on voluntary donation mechanisms.

5.3 United States: Legal Integration and Federal-State Coordination

The design logic of the U.S. public health system demonstrates significant advantages in terms of institutional integration and the transition between peacetime and emergency operations. Its core institutional design includes: the Federal Emergency Management Agency’s (FEMA) direct authority to coordinate the allocation of resources across state lines, and the Strategic National Stockpile (SNS) system established after the September 11 attacks, which guarantees nationwide distribution of supplies within 48 hours ^[26]. Legally, Section 319 of the Public Health Service Act authorizes the CDC to mandatorily deploy medical teams during interstate outbreaks and establishes a mechanism for compensation collaboration costs ^[27]. However, in recent years, the U.S. model has revealed a disconnect between institutional design and operational effectiveness—political interference, weakened resource guarantees, and systemic instability are eroding these institutional advantages. This suggests that legal authorization alone is insufficient to ensure collaborative effectiveness; it must be supplemented by stable political support and sustained financial investment.

5.4 Implications for China

Four key lessons emerge. First, institutionalized collaboration requires explicit legal authorization—China’s current reliance on administrative agreements is insufficient. Second, resource integration needs matching fiscal incentives; a cross-regional compensation mechanism is urgently needed. Third,

technical interoperability must prioritize standard harmonization before system integration. Fourth, institutional transplantation requires careful adaptation to China’s complex central–local relations and regional disparities—direct imitation of any single model is risky.

A comparison of international models and Chinese practices is presented in Table 2.

Table 2
Comparative Framework of International Models and Chinese Practices

Dimension	EU Model	WHO Model	U.S. Model	Current Situation in China	Directions for Reform
Governance Structure	Coordination by supranational bodies	Multilateral Partnerships	Permanent Command Structure	Administrative agreements as primary mechanism; no cross- regional legal entities	Establish regional coordination entities
Legal basis	Cross-Border Healthcare Directive	International Health Regulations	Public Health Services Act	Fragmented local regulations; no national-level collaborative law	Develop national-level collaborative regulations
Technical Integration	ECDC Unified Platform	HMF Indicator Framework	Mandatory Support for SNS Systems	Proliferation of provincial systems; poor interoperability	Build National Public Health Cloud Platform
Resource Allocation	Redistribution of Structural Funds	Voluntary Donation Mechanism	Collaboration Cost Compensation Mechanism	Locally funded; no cross- regional compensation mechanism	Establish special fund for regional collaboration

6 Policy Recommendations: A Dual-Track Synergy Mechanism Combining Institutional Restructuring and Technology-Driven Approaches

6.1 Pathways for Institutional Innovation

By establishing a tiered and categorized coordination system (e.g., consortia, funds, monitoring stations), a three-tier nested structure of “administrative regions–functional zones–risk zones” will ultimately be formed, achieving a dynamic alignment of central and local government responsibilities.

6.1.1 Tiered and Categorized System:

6.1.1.1 Developed Regions (Yangtze River Delta/Guangdong-Hong Kong-Macao Greater Bay Area): Pilot programs for a “Regional Disease Control Consortium” model may be explored. The central government should formulate the “Regulations on the Management of Regional Disease Control Consortia” to grant the consortium the following authorities through legislative authorization during cross-provincial public health emergencies: (1) Emergency Mobilization Authority: The consortium may direct member units to deploy personnel, equipment, and supplies; (2) Authority for mandatory mutual recognition of standards: Core standards established by the consortium’s council could be implemented in accordance with existing standards such as national and industry standards and take effect within member jurisdictions after undergoing relevant approval processes; (3) Authority for coordination and command: Unified coordination of cross-provincial operations during the emergency response phase. Concurrently, the consortium establishes a council, a three-tiered coordination system, and a supervisory committee. The decision-making council comprises the vice governors in charge of relevant affairs from member provinces (administrative decision-making), directors of provincial disease control bureaus (administrative coordination), and directors of provincial disease control centers (technical implementation), operating under a rotating chairmanship system (with the vice governors taking turns to serve as chair). The executive level is divided into a three-tiered coordination system comprising regional, provincial-city and district/county levels. The regional-level core institutions—comprising a standing secretariat, an expert committee, and a joint command center—are responsible for coordinating and integrating collaborative efforts, while provincial-city and district/county levels respectively establish joint sub-centers for disease control and prevention and consortium liaison points to execute coordinated responses according to their respective tiers. However, these consortia may encounter resistance from local governments concerned about fiscal autonomy.

6.1.1.2 Ecological Functional Zones (Yangtze River Economic Belt): Explore the establishment of a special fund for joint prevention and control of infectious diseases in river basins, and innovatively design a “two-way ecological compensation” model^[28]. The fund’s sources consist of: central government appropriations (40%), contributions from provinces and cities within the basin based on GDP proportions (40%), and ecological compensation transfer payments (20%). The compensation model is expressed as:

$$\text{Compensation Amount } (T) = K \times (C_{\text{monitor}} + C_{\text{prevent}}) \times R_{\text{risk}}$$

Where K is the compensation coefficient (determined periodically by the central coordinating body); C_{monitor} is the additional monitoring cost in upstream regions (e.g., additional monitoring sites, personnel); C_{prevent} is the cost of preventive measures in upstream regions (e.g., environmental remediation, population interventions); and R_{risk} is the actual risk reduction coefficient of upstream measures on downstream risks, assessed based on historical data and modeling.

Downstream beneficiary provinces and cities pay compensation to the Joint Prevention Fund based on the model’s calculation results. The fund is prioritized for compensating upstream costs, with the

balance invested in basin-wide capacity-building projects (such as laboratory network development and personnel training).

6.1.1.3 Border Regions (Yunnan/Guangxi): Cooperate with ASEAN countries to jointly establish cross-border disease monitoring and early warning stations ^[29]. Adopt a model of “China-led construction, multi-party joint operation and maintenance, and shared data sovereignty,” and introduce a “blockchain multi-signature decision-making” technical architecture to ensure the unity of data sovereignty and operational coordination. Drawing on the “authorization-as-consent” principle from the Guangdong-Hong Kong-Macao health code mutual recognition framework ^[30]—where data collected by a signatory institution under its domestic laws automatically gains legal recognition from other signatories, provided it meets common privacy standards—to directly support joint prevention and control efforts. Develop a standard template for the “Agreement on Cross-Border Infectious Disease Data Sharing and Privacy Protection” to overcome legal recognition barriers.

6.1.2 Standardization of the Standard System

The fragmentation of technical standards has become a “hidden barrier” to regional disease control collaboration, necessitating the establishment of a flexible mutual recognition framework ^[6]. First, regarding mandatory mutual recognition standards, the central government should issue and enforce a nationally unified “Technical Guidelines for Regional Disease Control Collaboration” to promote mutual recognition of standards in key areas such as laboratory nucleic acid testing procedures and quality control standards, classification standards for public health emergencies, standards for biosafety packaging and transportation of samples, classification and coding of emergency supplies, and technical specifications for personal information de-identification. Additionally, specialized specifications applicable to high-risk scenarios may be developed separately, such as the “Agreement on the Sharing of Genetic Traceability Data for Highly Pathogenic Pathogens.” Second, adopt a flexible framework design by expanding the dual-track standard system of “national standards + regional implementation rules.” Building upon national standards, allow each region to supplement them with implementation rules tailored to its specific characteristics. For example, the Yangtze River Delta region could establish AI early warning response thresholds (such as automatically triggering cross-provincial alerts when the basic reproduction number R_0 exceeds 1.5); the western regions could customize simplified rapid testing procedures, allowing for the streamlining of sample pretreatment steps under emergency or remote conditions, the use of more stable reagents, and the extension of the interpretation time window to ensure operability in special scenarios.

6.1.3. Institutional Support for Technology Implementation

Technology-driven initiatives require the establishment of a multi-dimensional institutional support system. Regarding data standardization and governance, there is an urgent need to formulate the “Guidelines for the Classification and Grading of Disease Control Data” to clarify technical standards for the de-identification of sensitive information. Otherwise, big data sharing and AI early warning efforts

will face legal challenges and security risks, making large-scale implementation difficult. In terms of computing power allocation mechanisms, regional computing center resource pools could be established to prioritize the computing needs of underdeveloped regions, narrow the technological application gap between regions, and promote balanced and coordinated development of regional disease control. Within the ethical review framework, regional AI algorithm ethics review committees must be established to guard against algorithmic bias and the risk of technological discrimination, ensuring the fairness of decision-making. Particularly in critical scenarios such as resource allocation and risk assessment, it is essential to prevent the occurrence of inequities caused by technical issues, thereby safeguarding the fairness and accessibility of public health services.

6.2 Technology Empowerment Plan

6.2.1 Digital Infrastructure

As the neural network underpinning the institution–technology synergy, digital infrastructure urgently needs to address practical challenges such as "hardware silos" and the "computing power gap." First, we must accelerate development of the National Disease Control Cloud Platform^[31]; integrate data interfaces from provincial-level systems; clearly define core datasets (including infectious disease reports, laboratory testing, symptom monitoring, resource inventories, and population mobility); and establish unified technical specifications for data access, simultaneously adopting "federated learning combined with privacy-preserving computing" technology as the core architecture to ensure provincial data is stored locally, exchanging only encrypted parameters or model gradients, thereby achieving "data availability without visibility (i.e., data usability without direct access to raw data)" at the provincial level. Second, plan and establish five regional high-performance computing centers, prioritizing the use of resources from the National Supercomputing Center or collaborating with major cloud service providers to meet AI model training needs.

6.2.2 Intelligent Application Scenarios

First, promote the application of the infectious disease risk "digital twin" model^[32]. By constructing a virtual regional disease transmission environment and multiple real-time data streams (e.g., meteorological, transportation) —the model simulates disease transmission dynamics under various intervention measures (such as lockdowns and vaccinations), enabling multi-scenario simulation and early warning capabilities. Its core value lies in supporting "scenario-response" decision-making, significantly enhancing the predictability of epidemic developments. Second, develop specialized lightweight applications (apps)^[33] to create "three-low" applications (low system requirements, low operational difficulty, and low data dependency). These integrate optical character recognition (OCR) report analysis and AI voice-guided triage functions to lower the technical barrier to use. Specifically addressing the limited network conditions in western regions, an "offline knowledge graph" module is deployed to support intelligent diagnosis and treatment recommendations based on symptom input in offline environments.

6.2.3 Technology Adaptability Design

To mitigate the “Matthew Effect” in technology adoption across regions, technology adaptability design may prioritize inclusivity to narrow regional disparities in digital infrastructure. First, western provinces may prioritize the deployment of offline AI early warning systems based on model distillation technology. By transferring knowledge from complex early warning models (teacher models) to lightweight models (student models), these systems can ensure efficient operation even on low-computing-power devices (such as standard computers at county-level disease control centers in western regions) [34]. Second, establish a “Special Fund for Technical Assistance”. This fund would focus on supporting equipment upgrades in western and underdeveloped regions (purchasing compatible offline AI devices and lightweight terminals); helping to increase the coverage of P2 laboratories in the west; and subsidizing travel expenses and allowances for technical experts from the east who assist in western development. Concurrently, complementary incentive policies could be introduced, such as counting the service period in the west as 1.5 times the required grassroots service years or workload for professional title evaluations, thereby accelerating the overall improvement of technical capabilities in the western regions.

6.2.4 Deployment Conditions and Ethical Risks

Deployment conditions include: Federated learning requires baseline data standardization and privacy computing capabilities—currently weak in many western county-level CDCs. Model distillation still requires at least one round of high-performance computing for teacher model training. Blockchain multi-signature architectures must comply with China’s Personal Information Protection Law and Data Security Law, especially for cross-border biosurveillance data.

Three ethical risks require attention: (1) Algorithmic bias—machine learning models trained on historically biased data may systematically disadvantage certain regions or populations. (2) Digital divide—advanced regions may benefit disproportionately, widening rather than narrowing disparities. (3) Data privacy—privacy-preserving technologies are not a panacea; robust legal and ethical oversight remains essential.

Governance recommendations: Establish regional AI ethics committees to audit algorithms for fairness; mandate regular bias testing for resource allocation and risk prediction models; maintain parallel offline service channels for populations lacking digital literacy.

Definitions of key terms related to technology enablement are presented in Table 3.

Table 3: Glossary of Key Terms

Term	Definition	Application Scenarios
Federated Learning	A distributed machine learning framework that protects privacy in cross-domain collaboration by keeping data stationary while moving models	Interprovincial Travel Verification
Model Distillation	A technique for transferring knowledge from a complex model (teacher model) to a compact model (student model)	Western Offline AI Early Warning
Blockchain Multi-Signature Decision-Making	An architecture where a predefined majority of signatures triggers the execution of smart contracts, ensuring cross-border data sovereignty	Yunnan-ASEAN Monitoring Station

7. Summary and Outlook

Promoting the coordinated development of regional disease control agencies is a key strategy for building a robust public health governance system. Through systematic analysis, this study finds that a policy framework for regional disease control coordination in China is taking shape, and practical models are shifting gradually from ad hoc emergency collaboration toward institutionalized co-construction and sharing. However, deep-seated institutional barriers have yet to be systematically overcome, and the realization of collaborative effectiveness remains constrained by multiple factors. International experience indicates that the establishment of institutionalized collaboration mechanisms, the efficient integration of resources, and the deep empowerment of technology are effective pathways to overcoming barriers to regional collaboration; however, these experiences must be adapted to China’s institutional environment and regional development disparities.

This study provides systematic theoretical support and practical guidance for building a modern disease control system characterized by “tiered and layered, regionally coordinated” structures, offering significant reference value. Looking ahead, collaborative research on regional disease control may need to focus on achieving breakthroughs in three core issues: First, the absence of legal safeguards, which requires accelerating the improvement of specialized legislation for cross-regional coordination to clarify the boundaries of responsibilities and authorities among all parties; second, the fragmentation of technical standards, which calls for promoting the dynamic optimization of standard systems and cross-regional mutual recognition; and third, the imbalance in resource allocation, which necessitates establishing more precise regional compensation and resource allocation mechanisms. At the same time, it is essential to remain vigilant against ethical risks in technology application, such as the impact of algorithmic bias on decision-making fairness and the potential exacerbation of regional development imbalances caused by the digital divide. Through the synergistic efforts of institutional design and technological innovation, we can continuously enhance the governance effectiveness of regional disease control collaboration.

Abbreviations

CDC Disease prevention and control agencies/ centers

EU European Union

WHO World Health Organization

ECDC European Centre for Disease Prevention and Control

HERA Health Emergency Preparedness and Response Authority

FEMA Federal Emergency Management Agency (US)

SNS Strategic National Stockpile (US)

PHSA Public Health Service Act (US)

HMF Health Monitoring Framework (WHO Europe)

HL7 Health Level Seven

FHIR Fast Healthcare Interoperability Resources

GDP Gross Domestic Product

AI Artificial Intelligence

OCR Optical Character Recognition

ASEAN Association of Southeast Asian Nations

Declarations

Availability of data and materials: Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Conflicts of interest: The authors have declared that no competing interests exist.

Funding: Chongqing Science and Health Joint Medical Research Project (2024MSXM172). and Shapingba District Science and Health Joint Medical Research Project (2024SQKWLHMS032)

Author Contributions

Conceptualization: Zhang Min.

Data curation: Zhang Min, Yang Tong, Zhang Chunhua.

Formal analysis: Yang Tong, Hu Bin.

Funding acquisition: Zhang Min, Yang Tong.

Methodology: Zhang Chunhua, Li Jun, Yang Tong.

Project administration: Hu Bin.

Validation: Yang Tong.

Writing – original draft: Zhang Min, Li Jun, Yang Tong.

Writing – review & editing: Hu Bin, Zhang Chunhua.

Acknowledgments: The authors thank the experts and staff members who assisted with data collection, organization, and the provision of policy recommendations.

✉ **Author Profile** ✉ Zhang Min (1978–), Associate Researcher, M.S., Research Focus: Public Health Management. Co-author: Li Jun (1972–), Senior Nurse Practitioner, Research Focus: Health Policy Research.

✉ **Corresponding Author** ✉ Yang Tong, E-mail: 850084969@qq.com

References

1. Zhu Cuiyue T, Shangfeng F, Hang, et al. Analysis of the collaborative development of medical service system and public health system based on composite system synergy model [J]. China Hosp. 2023;27(10):31–4.
2. General Office of the State Council. Guidelines on Promoting High-Quality Development of Disease Prevention and Control: State Council General Office Document [2023] No. 46 [A]. 2023.
3. Wang Z, Yifang LYL, et al. Exploration of the Development and Synergistic Model Construction of the Three Major Systems of China's Health Services from The Perspective of Healthy China [J]. Chin Health Serv Manage. 2025;42(06):601–5.
4. Lu Yin hao H, Xiaoyan S, Huaqing, et al. A Study on the Collaborative Joint Prevention and Control Mechanism for Public Health Emergencies in the Yangtze River Delta Region [J]. China Health Resour. 2023;26(06):646–52.
5. Zhu Min Z, Guoding W, Xiaoxiao, et al. Technical measures for joint prevention and control of imported malaria in the Yangtze River Delta: Experts consensus from Shanghai, Jiangsu, Zhejiang and Anhui [J]. Chin J Parasitol Parasitic Dis. 2025;43(04):458–62.
6. Liu Fuqiang L, Yi S, Jing, et al. Current Status of Regional Health Standard Integration and Practices in the Yangtze River Delta [J]. China Health Resour. 2023;26(06):653–7.
7. Daxing District People's Government, Beijing. (2018). Six regions in the Beijing-Tianjin-Hebei area sign cooperation agreement on coordinated development of health and family planning supervision

- and law enforcement [Government announcement]. Retrieved from <https://www.bjdx.gov.cn/bjsdxqrmzf/zhyw/dxdt13/605633/index.html>
8. Lü Xiaoli G, Jun X, Hao et al. Mapping out the Development of Inter-regional Agreements on Transboundary Crisis Management in the Beijing-Tianjin-Hebei Region [J]. J Gansu Inst Public Adm, 2018, (06): 48–57.
 9. Yuan Shuai. Combating the Pandemic: Coordinated Action in the Beijing-Tianjin-Hebei Region [J]. Xiaokang, 2020, (21): 40–1.
 10. Deng Shiyuan. A Study on Policy Coordination in the Governance of Public Health Emergencies in the Beijing-Tianjin-Hebei Region [D]. Changchun: Northeast Normal University; 2023.
 11. Cui F, Jiaxin L, Xingke W et al. Harmonizing the Twin Cities and Building an Optimal Health Circle: Deepening Health Integration in the Chengdu-Chongqing Region [J]. Popul Health, 2024, (07): 48–9.
 12. Sichuan Provincial Health Commission, Chongqing Municipal Health Commission. (2024). Ten actions to promote integrated health development in the Chengdu-Chongqing economic circle. Sichuan Local Chronicles Office. Retrieved from http://scdfz.sc.gov.cn/gzdt/zyhy/cyscj/content_140533
 13. Hechuan Daily. (2025). Hechuan, Guang'an, and Changshou reach strategic cooperation to promote coordinated development of disease control. Hechuan Daily, p. 2. Retrieved from http://szb.jrhcw.com/hcb/pc/202506/25/content_4382.html
 14. Dazhou Municipal Health Commission. (2022). Wandakai three regions sign cooperation agreement on coordinated development of health comprehensive administrative law enforcement. Retrieved from <https://wjw.dazhou.gov.cn/news-show-2836.html>
 15. Sichuan Provincial Health Commission. (2024). Chuan-Yu disease prevention and control collaborative integration work training meeting held. Retrieved from <https://wsjkw.sc.gov.cn/scwsjkw/gzdt/2024/12/9/b07177c5e1d445b1a6e85938099037fb.shtml>
 16. Ding Lisha F, Di Z, Zhaqiang, et al. Status of capacity building in disease prevention and control institutions in Hunan Province [J]. Practical Prev Med. 2024;31(08):1012–4.
 17. Huang Chaoqun. Study on the performance evaluation system for professional and technical capacity building in a provincial center for disease control and prevention [J]. Volume 28. Health Development and Policy Research; 2025. pp. 215–21. 02.
 18. Huang Lieyu L, Nana W, Yijie, et al. Analysis on Publishing Budget Changes of Provincial Centers for Disease Control and Prevention in China from 2021 to 2024 [J]. Chin J Health Econ. 2025;44(02):54–8.
 19. Yin Guanghui. A Study on Challenges and Countermeasures in Human Resource Management at Disease Control Centers [J]. Finance Econ, 2025, (08): 174–6.
 20. Wang Shifan Z. Reflections on the Construction of China's Public Health Emergency System in the Post-Pandemic Era [J]. World J Public Health. 2023;8(4):300–4.
 21. Mandel JC, Kreda DA, Mandl KD, et al. SMART on FHIR: a standards-based, interoperable apps platform for electronic health records [J]. J Am Med Inf Association: JAMIA. 2016;23(5):899–908.

22. European Health Union initiative [EB/OL]. [2025-10-21]. <https://europeanhealthunion.eu>
23. Organigram - WHO European Region [EB/OL]. [2025-10-21].
<https://www.who.int/europe/publications/m/item/organigram-who-european-region>
24. Stephen W, Romeu M, Tribuzi SM et al. Promoting health-enhancing physical activity in Europe: Surveillance, policy development and implementation 2015–2018 [J]. Health policy (Amsterdam, Netherlands), 2021, 125(8): 1023–30.
25. Rwamatwara E, Usman A, Ba SN et al. Public health workforce management during a major organizational reform in the World Health Organization African Region Country Offices [J]. Front Public Health, 2025, 131562732–1562732.
26. Yang, Muer, ,Kumar, et al. Scenario-robust pre-disaster planning for multiple relief items [J]. Ann Oper Res. 2021;1–26. 10.1007/S10479-021-04237-3.
27. Kufoof L, Hajjeh R, Nsour AM, et al. Learning From COVID-19: What Would It Take to Be Better Prepared in the Eastern Mediterranean Region? [J]. JMIR Public Health Surveillance. 2024;10(1):e40491–40491.
28. Yuan Weiyan. Research on the Key Influencing Factors and Mechanism Optimization of Payments for Ecosystem Services Based on the Principal-agent Model [J]. Modernization Manage. 2025;45(04):182–8.
29. Chen, Xirui. Yang Yue. China's Participation in East Asian Public Health Governance: Process, Characteristics, and Directions [J]. Volume 8. Studies on China's Peripheral Diplomacy; 2022. pp. 54–80. 02.
30. Wen H. Lin Bin. Technology Empowerment Mechanism of Cross Regional Collaborative Governance in Crisis Situation— Case Study of Taking the Cross-Border Health Code of Guangdong and Macao [J]. J South China Normal Univ (Social Sci Edition), 2023, (02): 39–50.
31. Xu Yanjí S, Ling ZQ. Impact of Medical-nursing Combination Services via theHealth CloudPlatform on the Quality of Life and Health-care Resource Utilisation of Elderly Community Patients with Chronic Diseases [J]. Chin Prim Health Care. 2025;39(01):47–51.
32. Chen Hao K, Ling, Wen Yunliang. Research on Digital Twin Water Environment Modeling and Response to Sudden Pollution [J]. Hydropower Energy Sci. 2025;43(08):32–6.
33. Hou Zhiying. An Exploration of a New Model of Social Smart Governance Based on Data Empowerment—Taking theSmart CangzhouWeChat Applet as an Example [J]. J Cangzhou Normal Univ. 2023;39(03):87–9.
34. Yang Yi L, Wei LZ, et al. Knowledge Distillation Techniques for Large Models Aimed at Industry-Specific Information Extraction [J]. Cybersecur Data Gov. 2025;44(S1):132–9.